Materials & Methods

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

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NEXT MONTH: ANNUAL ENGINEERING REVIEW ISSUE
Quality High Alloy Steels . . . Low Temperature Phosphate Coating . . . High Temperature Ceramics . . . Cycle Annealing of Steel . . . Extruded Steel Shapes . . . Compression Butt Weldings . . . Ductile Titanium . . . Plus ENGINEERING REVIEW, 1947 (Materials & Methods Manual No. 33)

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The MATERIALS OUTLOOK...

Scrap Still Steel's Biggest Problem—High prices are not bringing out the hoped-for scrap iron and steel, and won't, primarily because the scrap just isn't available. This situation is most serious with the small independent foundries. Reluctance to adopt new steelmaking techniques is probably perpetuating the problem. Steel can be made without scrap, or, synthetic scrap can be made directly from iron ore. Bureau of Mines claims to have one method which has proved out at around $12 a ton. While this price seems low, under present conditions it could be double and still represent a tidy saving.

Boxed Aluminum Sheet for Small Parts—Aluminum industry leaders feel that many small stamped parts and formed articles now made of tin plate, block plate and brass could be made more efficiently in aluminum. The only draw-back has been in obtaining the aluminum sheet in forms as convenient as the older materials. Now aluminum is being marketed as boxed utility sheet—cut sheets of various thicknesses. The sheet can be worked with standard sheet metal tools, and, on a volume basis, the cost of product is low because of ease of working and finishing.

Use Stainless, but With Caution—We should not be beguiled by the fact that stainless steel is now comparatively easy to get. It takes a great deal of chromium to make stainless, and chromium remains a deficit metal. Chromium is a AAA-1 material on the military strategic list. Also important is the fact that much of the high grade supply lies across a narrow area from Yugoslavia to northern India. The Soviet could walk in there at the drop of a hat. Stainless should be used for its special properties. When heavy plate is required, stainless clads can be used.

Secondary Lead May Be Scarcer—Too much optimism should not be read into the fact that in spite of big drops in receipts and stocks of lead scrap ever since last March, both receipts and stocks are still higher than at any time during the war. Lead scrap is important in the metal supply picture because, before the war, recovered lead from scrap constituted 50% of total production of refined lead. We cannot hope for that proportion of the supply now from scrap sources. Greater quantities of lead lately have been going into nonrecoverable uses. Furthermore, the high prices of the last year have brought most of the scrap into the market. Another point is that a high proportion of storage batteries made during the war are not coming back to us. Battery plates were once the biggest source of recoverable lead. American industry consumed an average of about 50,000 tons of recovered lead per month this year. A drop to about half that amount can be expected.

Nonmetallic Cutting Tools—Military authorities have released information on work done by Dr. Eugene Ryschkewitch on ceramic cutting tools for the Germans. The tools were made by sintering aluminum oxide powder. No metallic binder was used. Cutting speeds as high as 3000 ft. per min. were used in turning aluminum-silicon alloys with the ceramic tools.

Beware of Strategic Materials—In connection with metal futures, there is no movement in sight which would keep supply in pace with research into "super" metals needed for superchargers, gas turbines and jet engines, where high strength is needed at high temperatures. Some of these "super" alloys require as much as 50% chromium; some as high as 50% cobalt. Unless new foreign sources are developed, or new ways devised to utilize low grade ores, an extensive program to build the newest types of aircraft would cut off cobalt, chromium, tungsten and columbium from all ordinary uses.

Plastic Paints—There have been complaints that the term "plastic paint" has been abused since some of the finishes contained little or no plastic. Now, however, there are a number of real plastic base paints on the market, which, without baking, will provide finishes that are resistant to oils, alkalies and to staining. One new polyvinyl water-emulsion finish dries in a half hour to a hard, durable coating. In spite of the fact that water is used as a vehicle and thinner, such a paint will withstand repeated washings and scrubbings. Another new alkyd-urea-melamine paint gives good hiding properties on metal articles with one spray coat, and the finish is resistant to water and alkalies.

Chromic Acid Shortage—A severe shortage of chromic acid has caused a degree of hardship to a number of plating plants. The combined efforts of the National Association of Metal Finishers and the small business division of the United States Department of Commerce halted exportation of approximately 250,000 lb. of chromic acid during the final months of 1947. This action alleviated the situation somewhat, at least keeping it from getting worse.

Tin Still To Be Tight—Government materials experts are tightening their belts for a tussle with industries employing scarce tin in "non-essential" uses. The control powers inherited by the Department of Commerce from the defunct WPB are of dubious legality, but tin conservation is backed by the Munitions Board and will undoubtedly have public support. First to feel the effects of any crackdown will be tin plate for containers, except containers for acid foods, and tin plate for toys and novelties. Then, if necessary, it may hit high-tin solders and high-tin bronzes and bearing metals for all except applications where considered "essential." The tin metal supply predicted by the Tin Study Group last year hasn't materialized.

Metal Cutting Tools With No Tungsten—German technicians were able to produce a hard cutting alloy without the use of tungsten and cobalt. They produced titanium and vanadium carbides by carburizing the oxides in a hydrogen atmosphere. The carbides thus made were ball milled, sifted through a 1000-mesh screen, ball milled with iron powder, and then compacted and sintered. The sintered tools were used for machining steel, nonferrous metals and plastics. They have less strength than cobalt-bonded tungsten carbide tools, but show less cratering.

Why Export Steel Pipe—The reason behind recent approval for export of 20,000 tons of desperately-short steel pipe lies in the international political picture. The Near East is one of the world's greatest petroleum areas, and if British-American interests do not develop this field the Russians will. Before the British announced withdrawal from Palestine, the 1100-mile pipeline was switched to pass north of the fighting zone through all-Arab territory. Department of Commerce approval of the pipe export was routine; Army and Navy pushed the project as a military necessity. Many observers feel that this is only a start on future steel needs of the Near East.

Production Frontiers

by Harold A. Knight *News Editor*

Up From the Age of Jim Cracks

Because of our modern sophistication, we have lost forever some of the gew-gaws of life that were so dear to the pee-pul of the "gay nineties" and the eager eighties—such things as the wooden Indians in front of cigar stores, the large globes of colored liquids in drug stores, the cast iron or cast bronze deer on the lawns of the well-to-do, the ingenious mechanical toys that did everything from playing a squeaky fiddle to shaving a bearded giant.

There is one prosperous manufacturing concern that started in such an era with typical products of those times—sheet metal statues, cornices and various ornamental jim cracks, but kept pace with the times, evolving through metal boats, metal laths, signs, cook stoves, gas pumps, radiator covers, auto trailers, window frames, washing machine tubs, automotive stampings and kitchen equipment.

The Mullins Manufacturing Corp. tells it all in an attractive booklet, "The Story." They acquired fame early in life by making out of sheet metal the noted statue of Diana which graced the top of Madison Square garden in New York for so many years—a statue whose nudity shocked the good people of the nation.

The "story" is 75 years old. The Pennsylvania Railroad sold a wrecked locomotive at auction, the highest bidder having been William H. Mullins. After he had dismantled the locomotive and sold the parts, he had $1000 with which to buy into a manufacturing business at Salem, Ohio. Within a few years the company's sheet metal statues were known throughout the world. It was the Victorian era in American architecture when buildings were really fancy.

The desired figure was modeled in clay, and from this plaster casts were made. From these, dies for the hot stampings were fashioned, the lower die of cast zinc and the upper die of lead, the latter fastened to a drop hammer. Hot stamping was a ticklish business and a perfect stamped part was a tribute to the workman's skill. The stamped parts were assembled and soldered together. When the joint was smooth it was almost invisible. Such stamped statues rapidly replaced those of carved stone or cast bronze because they were cheaper and lighter.

Most famous was the 18-ft. goddess Diana atop the old Madison Square garden (then on Madison Square), designed by the great sculptor, Augustus St. Gaudens. He arrived in Salem in 1890 to work on the plaster model of the huntress. Temperamental, he threatened to give up the whole project when Diana's big toe fell off the plaster model. Luckily a successful impromptu operation, unknown in the archives on surgery, was resorted to and presto!—the toe was in place and the situation was saved.

When that hussy, Diana, was installed above New York's busy streets, women's clubs demanded that this shameless creature be taken down. Newspapers increased their circulations by arguing pro and con. At length St. Gaudens added draperies of a sort which he later removed because they spoiled the harmony of the figure. Used as a weathervane, Diana registered the most fickle winds and the varying sentiments regarding her nudity. At length she was shifted to Chicago, and in 1932 the 1500-lb. sheet copper statue came to final resting place at the Pennsylvania Museum of Art in Philadelphia. The sheet metal employed by Mullins was copper, bronze and zinc, the copper, of course, costing the most.

There are, in fact, many interesting Mullins anecdotes brought out in "The Story." Their choices of new products during the changing eras were usually happy ones, though they were not without their share of troubles. Indeed, their history is the typical one of the old American enterprise that survives today, which knew when to shift its products, yet kept within lines it was capable of manufacturing. "The Story" should be

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must reading for the student who wishes to learn what made America tick industrially through all these years.

Another Metal Show

Once more we have returned from our annual jaunt to the Metal Show. By this time our feet have recovered from their weariness and our mind has had a chance to evaluate the Show and the concurrent meetings.

Our general reaction to the Show is less than enthusiastic. This is likely due to a number of things, including the location of the show arena, scattering of meetings all over Chicago, chopped up layout of the show building, and the fact that there was too little shown that was new.

On the favorable side is the new plan of cutting down on the number of papers presented at the technical sessions. In former years those interested in hearing papers were often confronted with the problem of deciding which of three or four papers they really should try to hear.

Perhaps the most interesting of the new equipment shown was the automatic flame hardening machine developed by the Cincinnati Milling Machine Co. Whenever we approached this booth there was an interested crowd watching the machine automatically heating, quenching and conveying a production job.

Just how rapidly progress is being made in the field of metals engineering was forcibly brought home by Carboloy in its booth. Can you imagine any such booth a few years ago not being filled with cutting tools of all shapes and sizes? This year Carboloy's booth didn't have a single cutting tool. There are now so many other applications of carbides that the exhibit was completely built around them.

While there was considerable griping about the show's location in the vast Chicago stockyards, we noticed that a good percentage of the visitors took advantage of the location to fill up on the steaks available in the Saddle and Sirloin Club. They were good!

Our over-all reaction to the Show is that we would have missed little if we hadn't gone. Three shows in less than two years doesn't permit too much time for developments to reach the state where they can be shown. On the other hand, sponsors of the Show insist that if there were no demand for the Show it wouldn't be successful. Our contention is that mere attendance is not a guide as to the usefulness of a show. Many of those attending an affair of this type are drawn to the technical meetings and visit the show casually.

Washington Words of Wisdom

As has been mentioned in these columns before, a session for business paper editors is held every six weeks or so in Washington. Their purpose is to provide editors with background information on governmental activities. The impression gained from the last visit is that everyone in Washington has some active interest in the so-called Marshall plan. Most of them are for it—but most also feel that their department, bureau or what-have-you, should have charge of handling the distribution of mountains of supplies to be given, loaned or sold abroad.

Although there is much room for doubt, some officials declare that exports planned under the Marshall plan will not exceed shipments abroad this year. Several pointed out that one of the problems is to siphon off the weak currency of many Western European nations to reduce the inflationary tendencies existing.

Everyone seemed to concede that some type of relief plan would be put into effect, but no one would stick his neck out to predict the amount or duration of such relief. Stricter export controls will be required over many items—particularly steel—if the program is to keep inflation from getting out of hand at home.

Taking its cue from England and France, Washington has become aware of the need for high industrial productivity as another barrier against inflation. In England, the fact that workers have too much money in relation to the goods available has resulted in the attitude: "Why work, we can't buy anything anyway?" So, they take a few days off each week and over-all production drops.

No matter from which direction you look at it, the world is in a bad way, politically, physically, economically, mentally and morally.

Pollution by Industry

Every so often an industry bobs up as a public nuisance, try as hard as it may to eliminate its anti-social features. Many a manufacturer has polluted streams and killed fish by depositing waste products in them. Others, such as metal smelters and refineries, have thrown off obnoxious gases that have killed vegetation, including farm crops, for miles around. Along comes a new form of public nuisance—though we hasten to add, intelligent steps are being taken to correct it.

We refer to high frequency heating machines that tend to interfere with radio broadcast receiving, with television, commercial and airplane radio messages. At a recent meeting of the Induction & Dielectric Heating Apparatus Div., National Electrical Manufacturers' Assn. at Atlantic City, which one of us attended, progress was reported through cooperation between equipment makers and the Federal Communications Commission. Dielectric heating is the chief offender.

Three allocations for industrial, medical and scientific equipment were granted by the F.C.C. on May 17, 1945—13.66, 27.32 and 40.98 megacycles, with plus or minus 0.05% tolerance for the first and third, and 0.5% for the second.

A public notice has been issued by F.C.C., proposing that additional frequency allocations be made at approximately 6 meg. per sec., and at 915, 5850, 10,600 and 18,000 megacycles per sec. Hence, it would seem that this government body is making every effort to help the high frequency heating industry find a place in the radio frequency spectrum.

Thus, another form of industrial pollution is being solved.

Shotguns

Many of the finest sportsman's shotguns ever made were manufactured within our lifetime, but today they are as obsolete as the defunct dodo, although they still function perfectly. Their barrels were made by the twist or laminating process, formed by wrapping a strip of steel spirally over a core. Such guns were marvels of beauty and balance, states the Lindberg Steel Treating Co. in its house organ. The twisted strips were welded or brazed together, the core removed and the bore completed. Instead of the modern bluing process,

the barrels were browned and polished to a beautiful finish.

Many of the ancient masterpieces are around today, in hands of collectors and owners. But they aren't safe since modern smokeless powder loads of minimum velocity may burst them after a few shots. The high speed powder charges used for shooting ducks and geese at long range would blow them to kingdom come. Modern shotgun barrels of alloy steel are proof tested with double the loads that would shatter the firearms of our fathers.

The transition from the old twist or "Damascus" barrel to the modern shotgun is mainly a story of metallurgy and heat treating. Some of the finest gun steels in the world are made today in American small arms plants and heat-treated by methods originating here. Other fine gun steels are made in Birmingham, England. There and at London gun making has reached high perfection.

There's more that meets the eye than the barrel. Coil or V-shaped springs drive the firing pin against the primer, and in the life of the average gun these springs are compressed and released many thousands of times. As many as 250,000 shots have been fired from inexpensive American guns, and probably another quarter million would find them working perfectly.

The great majority of American guns sell under $200, whereas fine guns of England range up to $1500 and while the latter may be more delicate in balance and "feel", they perform no better, nor last longer.

The secret of the good American guns is heat-treating. American steel treating is unexcelled.

Lukens: Where History Is Made

What the United States does not have much of by comparison with Europe, for instance, is history. A span of 154 years, by American standards, constitutes genuine history and this is the span of the Lukens Steel Co., which held open house in a rather elaborate way on Sept. 11 to an impressive list of government leaders, publishers, editors, radio commentators, industrialists and others.

There is much that is fascinating in the history of Lukens, best known because it can make the widest steel plate in the world—195 in. wide, or 25 in. thick, weighing as much as 111,000 lb. It was a Lukens plate that first furnished armor for an American battleship, the S. S. Codorus—using the plates in boiler and hull.

It has been a company of sons-in-law. The present company's name is in honor of the first son-in-law, Dr. Charles Lukens, originally a physician who switched his doctoring from humans to sick iron-making machinery. Abram Gibbons, Jr., son-in-law of Mrs. Rebecca Lukens, became a partner in 1843, as did Dr. Charles Huston, another son-in-law in 1849.

A son-in-law of Abram F. Huston, one-time chairman, is the present president, Robert W. Wolcott.

In 1793 a young Quaker farmer, Isaac Pennock, purchased a mill at Rokeby, four miles south of Coatesville, Pa., setting up a "slitting" mill, the first product being charcoal iron rods for general blacksmithing use. Later the rolling of sheets and manufacture of cut nails were added.

Perhaps the most remarkable phase of the company's history was the management of the mill by Rebecca Lukens, daughter of the founder, who presided from 1825 to 1854. Widowed at 31, she took over a nearly bankrupt iron works and developed it into one of America's important steel companies, bringing up four children meanwhile.

Rebecca adored her father and was fascinated by the mechanical workings of the mill. She observed that her father was fair and generous with his workmen; she heard him drive fair, but shrewd bargains for his raw materials and on sales of his goods; she absorbed from him his courage.

Upon her father's death her husband took over the mill and upon his death in 1825 it was thrown into her capable lap. Though she had received no training for business she had been schooled in organizing and running a house. She herself bought mill supplies, studied prices, met prospective customers and attended to their inquiries and orders.

Rebecca studied legislation that affected her business and campaigned with other iron masters for a sufficiently protective tariff. She built tenant houses for her workers, and when it was necessary to raise production to 500 tons yearly she created an incentive fund. In 1837 she was confronted by a severe business panic. A neighboring mill owner quarreled with her for years over water power rights. She was saddened by a lawsuit over her father's will.

She was justly proud of her enterprise—"a very superior mill, though a plain one." In 1844 she wrote: "Our character for making boiler plates stood first in the market."

Despite her business responsibilities Rebecca led a well-rounded life. In early years she read all the books and periodicals she encountered—and late into the night. She relished entertaining and passing the time of day. She found plenty of time to tell her children bedtime stories. She was an expert horsewoman.

It has been the thousands of Rebeccas who have contributed immeasurably to America's success. And it was hundreds of persistent ironmasters of yore—like the Pennocks and Lukens—who laid the foundation for a United States steel production that is now larger than all of the rest of the world together.

A Strike!

There was a standard gag during ye olde minstrel days that ran as follows: "Sambo, you seem to be steadier and less nervous than you were. How come?"

"Well, Mr. Bones, I now lives in a quiet and restful place—So quiet you can hear a pin drop. I lives over a bowling alley."

Those were the days of wooden pins. Comes Light Alloys, Ltd. of Renfrew, Canada, with a magnesium bowling pin which they claim is uniform, accurate in weight and dimensions and of long life.

We can imagine, too, that they are less noisy when they drop. To begin with, magnesium has a dampening effect against vibration, which is one of the points in its favor as wheels of airplanes and automobiles, for instance. It will be interesting to see how the "mag" bowling pin holds up under impact and abrasion. And how will it behave when the bowling alley is at a humid seaside summer resort such as Atlantic City? It should not swell, contrary to its wooden cousin.

As to its probable bowling qualities, from the sports standpoint, we'll have to consult our sports editor, T. C. Du Mond, editor of "The Last Word," page 212, a bowler of no mean scoring ability. What say, Ted?

AN EDITORIAL

Dear Reader:

This really isn't an editorial so much as a letter to you from us concerning the work that you do and the kind of assistance in that work that this magazine can render to you. It isn't a "sales" letter, either, since you're already a customer—*i.e.* you're a reader of the magazine. Perhaps you might regard it as a "service" letter, inquiring as to whether you're getting the most you can out of this publication and suggesting means by which you might increase its utility.

Your working life today (as ever) is full of problems. Since you are a reader of M&M we may assume that these problems are largely concerned with the materials to be used or being processed for some kind of fabricated products. We consider our mission to be easing your way through the labyrinth of questions and decisions on materials and their processing you must face—what new materials are available? What are their characteristics in comparison with older materials? What material is best for each specific application? What standards, specifications and tests exist for the material you want to use? What is its supply and price situation?

Again, can a material under consideration be processed using the methods and equipment available in your plant? Which types of raw-material parts should be considered for a given product—forgings or castings or screw machine products or stampings or plastic moldings or what? What finish should be applied to improve the beauty or surface characteristics of a material? Which processes should be employed with the material selected—what methods and equipment for forging, forming, heat treating, welding, machining and finishing give the best results and the least trouble with it? How can you eradicate the "bugs" that accompany the hardening or the machining or the soldering or the casting of a certain hard-to-handle material?

The purpose of your editors is to provide the kind of information that will help you to answer these questions and dozens of others like them. Obviously no technical magazine can supply ready-made the correct, detailed solutions to your specific and often complex problems, but engineering journals can and do supply the background and formulas from which you can efficiently extract your own solution. In our case we publish descriptions of new materials, descriptions of new processing methods and equipment for materials, engineering data on the properties and workability of all types of materials, comparisons of specific materials and processes based on "case history" examples, detailed procedures recommended for processing individual materials, and specific solutions for some widely-met problems worked out by certain plants. We try to provide in one general and continuing program *all* the background information on materials and their processing which an intelligent engineer, metallurgist or production man would require for solving his "materials" problems.

All this is of little value to you if we fail to delineate our coverage clearly enough or to organize our material efficiently enough for you to seize upon it and use it as the effective engineering tool it is designed to be. This "letter" should explain what we *are* doing as an information purveyor, so that you can make the maximum use of the service as presently constituted.

Now why don't *you* tell *us* what additions to or improvements in this editorial program would make it even more valuable and interesting to you?

FRED P. PETERS

EDITORIAL COMMENT

Make It Smaller, Make It Lighter, Make It Work

At a symposium upon printed circuits held in Washington, Capt. Frank Akers of the Naval Bureau of Aeronautics told the group that at the outbreak of the war a sign had been hung in one of the bureau offices reading "Make It Smaller, Make It Lighter." Later, someone added to this "Make It Work." This need for smaller, lighter equipment, always pressing in aeronautics, has become a general trend throughout industry, and there is every reason to believe that it will continue with increased force.

Later, speakers at the same symposium pointed out some of the less obvious reasons why the military sought smaller, lighter equipment, and these reasons are well worth calling to the attention of industry in general. In all branches of the transportation industry there has been, of course, the recognition that any dead weight above the necessary minimum reduces pay load. Manufacturers in other industries are beginning to recognize that larger, heavier machines or parts frequently represent uneconomical use of material; that they require higher bulk inventories; that they are sometimes more costly or less reliable in operation when used in moving machinery, and that they require more plant space for their fabrication. These reasons are not universal, by any means, but they are frequently applicable.

The printed circuits being considered were an excellent case in point. In addition to light weight, they made possible the wiring, by semi-automatic processes, of a complete circuit, replacing the slow and costly construction of cord sets or placing of wires one at a time. The pile of wire of many sizes became a silver paste; resistors were no longer stocked in a range of sizes, but were made up to requirements from basic ingredients. (Incidentally, it was this very development that won the grand prize in the 1947 Materials & Methods Achievement Award, announced in our last issue.)

The fact that a manufacturer can now pay a premium for materials that will save on swollen labor costs is one of the most significant recent changes in the materials and processing outlook. It is equally true that the materials engineer can now make a substantial saving if he can reduce the amount of these more costly materials needed for a given piece of equipment, without impairing the efficiency or operation of that equipment. We find, then, the tendency toward miniaturization following closely behind the trend toward increased mechanization of processing.

Another factor of considerable importance in the trend toward miniaturization is the growing use of automatic equipment. Automatic or remote controlled equipment, unattended or infrequently examined, must have a high guaranteed life rather than a high average life, and light weight will in many cases make possible the longer life of such equipment.

These are new, but very important, trends in industry as it concerns the materials engineer. Present indications are that they will be intensified, with still higher wages as a possibility, and that they will constitute the broad picture of industrial production progress for our present decade.

—K.R.

Plea for Natural Materials

The desire for imitation is one of the foibles of the American people. They say that the first automobiles had a whip socket on the dash board to imitate a buggy. One has seen from the train rows of houses in the poorer districts, where flat roofs were disguised by a triangular front to give the impression of sloping roofs. One has observed steel panels of radio receiving sets and steel furniture given a finish to resemble grained wood.

In recent years we heard a wail from an aluminum manufacturer — a wail that ended in a note of hope—to the effect that some day aluminum would be made to look like aluminum, and not some other material. Having just then seen some aluminum door knobs and other household hardware given a finish to resemble brass, we could appreciate what was meant. That same aluminum is one of the most versatile materials to take finishes that resemble some other material.

We recall a clubhouse at which we were entertained, in the heart of an aluminum-producing district, where many trimmings were of aluminum, with no attempt to disguise it. Shower-bath walls were of sheet aluminum, with attractive embossed patterns, and on which labor costs to install were trivial. Lighting fixtures were equally attractive and wrought in the manual training department of the local high school. To carry out the harmony, officers of the club smoked cigarettes in plain aluminum holders. The over-all effect of this aluminum decor in its untampered-with state was pleasing.

And then we are reminded of an article in *Finish* magazine by Don Graf, a leading expert on materials in the architectural field. Said Mr. Graf: "A glance back through the five thousand years of recorded architectural history will reveal no example of a building product getting anywhere if used in imitation of another."

He says further that 90 years ago Charles Ruskin wrote "The Seven Lamps of Architecture," one of the "lamps" being honesty—honesty in the use of materials. Mr. Graf gives as illustration stainless steel tiles. He points out that as to stainless, its inherent characteristic is that it is absolutely uniform in surface, can be made in large unbroken panels sans joints, and with no color variation.

"Why cut it up into little squares, making its installation more expensive and impairing the sanitary aspects of the wall with useless joints?" asks Mr. Graf, answering his own question by remarking that stainless steel tiles died aborning when offered on the market.

Can't we all recall many instances where metals, left in their natural state, have proved truly beautiful? A copper roof on an old city church, rich in its natural patina? Or perhaps one of the more modern rigidized materials, where a pattern is rolled into a metal strip by a process superior to embossing, not only stronger, but pleasing appearance because of its three-dimension, two-toned effect?

So, designers and engineers, think twice before you try to disguise a metal or other material.

—H.A.K.

How to make . . .
THREE tons of steel do the work of FOUR

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Materials & Methods THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE
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Engineering Economics of Magnesium

by HAROLD A. KNIGHT, *News Editor*, MATERIALS & METHODS

MAGNESIUM HAS BEEN DESIGNATED by some of its best friends as a "Johnny-come-lately." Since it is one of the newer engineering materials, it has had its ups and downs; its boosters and knockers; its ideal applications and misapplications.

The material has had to fight to gain headway in fields long taken over by older metals. Magnesium has found applications where it fitted ideally and others where it did not fit at all. Many potential users have tried it and given it up for many reasons, principally lack of knowledge of how to apply it or process it. With all this, magnesium is gaining steadily on the more deeply entrenched metals. As its uses have increased, its price has come down, so that now, for some uses it is the cheapest material available.

Many a modern man has chucked magnesium and gone back to more time-tested materials. A maker of communications equipment, toying with magnesium, threw it out the window, figuratively, because he learned his fire insurance policy would not permit magnesium in his laboratory, pilot plant, or factory without raising the insurance premiums.

A maker of electronic air filters abandoned magnesium mainly from the standpoint of cost after many time studies. However, these instances are not typical and often reflect inexperience with magnesium.

Offsetting that pessimism, note Table 1, which compares the complete costs of making a reservoir for an oil lubricating machine where one material tried was cast iron, the other magnesium. For the 2-pint size, the magnesium was 32.3% cheaper while for the 4-pint reservoir magnesium was 12.4% less.

The key philosophy is about as follows: There are hundreds, perhaps thousands, of applications, where magnesium can compete economically today; there will be hundreds of thousands of such economical applications five to ten years from now. Thus, when magnesium is rolled on continuous sheet steel mills (and it has been demonstrated that it can be done) and other mass production methods have been developed, the magnesium price will be lower and uses will have forged ahead.

General Cost Advantages

In an analysis of comparative costs of magnesium alloys, it is necessary to base the analysis on the assumption that the product will have increased saleability due to the characteristic properties of magnesium. Or, due to shortage of cast iron or other material, the manufacturer is forced to use magnesium.

It is useless to pretend that direct volume-for-volume cost of a magnesium alloy in comparison with another metal will be favorable to magnesium, or even equal in the majority of cases. There are specific applications where one can redesign or make adjustments in a product so that the price per piece will be comparable, or even better than, say, cast iron. But these changes probably entail re-tooling, machining changes and assembly adjustments—hard to justify except on a long-term basis.

To approach a potential magnesium customer on the basis of pure comparative price is sometimes disastrous unless considerable thought is given to the customer's usage and requirements. It must be established that the customer has a bona fide use for the magnesium alloy. Then the comparative cost of the magnesium alloy with the material he is using must be analyzed.

One must present the amount of hidden value which may take one or more of the following four forms:

1. It is the lightest commercial metal in use and the manufacturer can decrease his material handling costs and increase the efficiency of moving the material through his plant.

This magnesium truck train weighs 6000 lb. less than its counterpart made of the lightest possible steel. Thus, it can carry 3 tons more of payload than otherwise, in this instance cement, amounting to a year's saving of $3,859.20. The life of the truck train is estimated conservatively at 6 years.

2. Magnesium machines better than any other common metal—heavy cuts at high speeds, decreasing power requirements and increasing machine efficiency. Using a power index of 1 for magnesium, power requirements for other metals rank: aluminum alloys, 1.8; yellow brass, 2.3; cast iron, 3.5; mild steel, 6.3; and nickel alloys, 10.0.

3. Freight and shipping costs are lowered on incoming materials and finished products.

4. Greater saleability, possibly at a premium price, should absorb higher raw material cost. (A department store head recently stated that "magnesium" and "nylon" are the most magic sales words.)

Magnesium Prices

Magnesium prices will be tied very closely to those of aluminum on a volume or footage basis for an equivalent cross section. There is only a small differential between magnesium and aluminum prices, multiplied by 1.6, the volume or footage factor for the difference in specific gravity. This generally applies for rounds, bars, tubes, shapes, hollow extrusions, wire and extruded strip. It does not apply for magnesium plate or sheet, which is substantially higher in cost than aluminum sheet and not particularly related for the various individual gages and sizes. Magnesium sheet, on a volumetric equivalent basis, is from 25 to 100% more than aluminum because of the manufacturing process and characteristics of the material itself. Magnesium sheet will have only special uses, therefore, such as bulk stiffness applications in aircraft, or portable facilities, or where welding advantages, deep drawing considerations or other property might compensate.

Magnesium extruded products, however, can compete with aluminum and will be applied with aluminum sheet such as truck bodies, railroad cars and other capital equipment items.

Commenting on the high price of magnesium sheets, let us refer to a significant statement of Dr. J. D. Hanawalt of Dow, who says that on the present conventional magnesium rolling mill the 200-lb. slabs are expensive to cast and scalp. The small slab is broken down so slowly in the rolling mill and handled so much that it cools off and must be reheated several times.

But let us see how magnesium performs on a modern continuous strip steel mill. Cast slabs of Dow FS alloy were put through a reversing breakdown mill with enough speed and power that the magnesium actually became hotter rather than cooling off while being rolled down from 7 in. to 0.4 in. in 2 min. It was passed on hot to the tandem mill, coming out and being coiled at 1200 ft. per min. a moment later as 0.050-in. sheet. Aluminum has already made the transition from small mill to continuous mill. Aluminum slabs, 2000 to 3000 lb. each, are rolled and coiled without hand labor and reheating.

Magnesium vs. Other Metals

Prewar values are of almost no use in comparing fundamental costs and prices. Several have successfully invaded the conventional cast iron market with magnesium, especially in the lawn mower and X-ray equipment field. Some of these parts are magnesium alloy moving and working parts, not merely housings and containers. They are fabricating magnesium lawn mower parts which are identical with prewar cast iron parts at a competitive price per pound, taking weight ratios into consideration. Here, and for the X-ray equipment maker, there is no reason to believe the customer will ever revert to cast iron.

Several find no particular difficulty in replacing aluminum with magnesium where the application shows a distinct advantage, and any slight premium which accrues to the price is usually acceptable on a volume-for-volume basis. Some sell both aluminum and magnesium parts and are impartial between them.

By far the majority of magnesium applications are based on a desire for weight saving and at a higher overall cost than for the material supplanted. In aircraft, weight saving is variously estimated as worth from $5 to $100 per lb. of weight saved. Aside from aircraft, a reduction of dead weight in portable or moving equipment will justify a higher cost because of greater production speeds or elimination of worker fatigue.

In some cases a magnesium assembly can be built

up that saves *both* weight and cost because of certain characteristics involved in the construction. This often happens where something is constructed with equivalent strength, where weight elimination is not of major importance. Thus, Beech Aircraft Corp. substituted a magnesium monocoque stabilizer for one of aluminum, in which equivalent strength was obtained with 6% reduction in weight and 35% reduction in cost. The key to the saving was elimination of certain internal strength members.

Magnesium dockboards in the place of steel have weight ratios of 100 lb. to 260 lb. of steel, the final assembly being just as cheap as steel. Magnesium sheet airplane oil tanks, welded, have proved lighter than aluminum and at about equivalent cost. Magnesium warp beams for the textile industry are as strong as aluminum, lighter and little, if any, more expensive.

Another company in Michigan used a 6000-lb. steel and wood refrigerated meat truck, but redesigned it for magnesium, cutting the weight to 3,000 lb. In that state license fees are based on weight and the saving for this meat truck on license fees alone was $51 per year. Lightweight bodies also tend to localize unavoidable damage and actually protect engine and chassis by absorbing shocks.

The processing cost of magnesium has heretofore been the result of an overloaded technique and procedure condition. The magnesium industry has been inclined to bend over backwards to insure soundness and quality of its product since many an infant industry has been ruined, or set back, by indiscriminate application, over-selling and poor manufacturing technique.

There are practical indications that some of the processing costs of magnesium can be lowered or eliminated. It is indicated that by such steps in some applications the physical properties, such as corrosion-resistance and surface strength, are improved.

In comparing the ingot price of magnesium of 20½¢ per lb. with aluminum at 15¢, we find there is 16 cu. in. of magnesium in a lb. as against 10.28 cu. in. of aluminum. One can thus buy 1.5% more volume of "mag" for the same money. (1 cu. in. of magnesium costs 1.3¢; 1 cu. in. of aluminum costs 1.46¢.) This is not enough to offset the processing costs of magnesium. The experience of many is that the processing cost of magnesium is 10% higher than for aluminum. The ratio of volume per dollar is way out of line, though magnesium gains by its physical properties in many uses and by the fact that cast iron parts are invariably over-designed and excessively heavy.

Usually where magnesium competes with steel it is in the form of cheap magnesium stampings. No one can claim that magnesium approaches the physical value of steel except from the light weight standpoint.

Machining on magnesium sand and permanent mold castings can be done at 15% saving over aluminum and at 25% over cast iron. In making aircraft landing wheels the machining economy about counterbalances higher sand castings costs. If the wheel manufacturer had to machine aluminum landing wheel castings he would have to largely increase his machining equipment and floor space.

Magnesium in Aircraft

Magnesium, where feasible, is a "natural" for use in aircraft. At a recent exhibit of the Magnesium Assn. one saw a very complex magnesium casting used for oil equipment in a de-icing unit. It is not only lighter than the aluminum component previously used, but is actually cheaper in cost.

A floor beam of the Douglas C-47 was redesigned of extruded magnesium, making a beam that was 35% stronger, 25% cheaper and 5% lighter.

At the Beech Aircraft Corp. it has been found that an all-metal surface could be made of magnesium, so light in weight that dynamic balancing problems are easily taken care of, possible because magnesium is only two-thirds the density of aluminum alloys. Magnesium construction can be simple and involve relatively few and inexpensive parts, except that the actual cost of material is greater per pound. However, substantial savings accrue over previously-used fabric-covered control surface design.

While few of the present light airplanes have made use of magnesium, that is because most of them are still prewar designs. Magnesium gives superior quality castings and better casting work can be done with it than is possible with the aluminum alloys.

Toward the end of the war the Navy Department actually requested that magnesium castings be used as much as possible for Navy aircraft armament, and since these were continually used on salt water, it can be assumed that the corrosion problem was overcome. Magnesium castings have extremely good shock-absorbent qualities, and are desirable from the engineering point of view. Stressed skin is a good usage for magnesium.

Though magnesium is more expensive than aluminum, the difference is only about 33⅓% more by weight and it is the same price by volume. The stainless steels are comparatively expensive. The weldability of magnesium is one of its outstanding features. One can obtain welding efficiencies of 85 to 90%, impossible with aluminum alloys. New rubber blanket materials make it feasible to produce magnesium parts by the Guerin process at sustained temperatures of 450 F, placing the material on a competitive basis with aluminum in this respect.

Magnesium sheet from 0.051-gage up can be welded. Wing covering might be readily built up in this manner. The sheet cost is about 60¢ per lb.; casting cost, $3 per lb. These castings require little fabrication since their surface quality is easily controllable, both dimensionally and in finish.

A magnesium test wing built and subjected to exhaustive tests in comparison with an aluminum wing gave favorable results. The tests were made at the Naval Aircraft Factory, under direction of the Bureau of Aeronautics. This outer wing panel for the SNJ-2 airplane weighed 182.21 lb. made of magnesium as against 212.5 lb. from aluminum. The magnesium panel was adequate in strength and endurance. Moreover, because magnesium meant substitution of a light, thick single member for thin-skinned complex structures, the cost was decreased.

It is apparent that the trend of design is principally toward the metal monocoque fuselage and cantilever

Costs of Lubricator Reservoirs (Cast Iron and Magnesium)

2-Pint Reservoir (5¾ in. by 5¾ in. by 3¾ in.)							
Material	Weight, Lb.	Casting Cost	Number of Machining Operations	Machining Cost	Machining Time	Total Cost Machining and Casting	Saving
Cast Iron	8.9	$0.98	12	$2.05	*.466 Hr. or 28 Min.	$3.03	—
Magnesium	2.22	$1.25	12	$0.80	.18 Hr. or 11 Min.	$2.05	$0.98 (32.3%)
4-Pint Reservoir (6 in. by 6 in. by 6 in.)							
Material	Weight, Lb.	Casting Cost	Number of Machining Operations	Machining Cost	Machining Time	Total Cost Machining and Casting	Saving
Cast Iron	13	$1.52	12	$1.83	*.414 Hr. or 25 Min.	$3.35	—
Magnesium	2.66	$1.57	12	$1.51	.319 Hr. or 19 Min.	$3.08	$0.27 (12.4%)

* *Lesser time for larger reservoir due to accessibility during machining.*

Here in black and white are actual cost savings in dollars and cents, magnesium over cast iron, in a part of an oil lubricating machine

wing, which has been publicized by the large number of such designs in use during the war. It is time to ask: Why not use the right light metals in thick gages and save the cost of most of the internal auxiliary parts?

Assuming that metal skin structures are desirable, the relative cost, coupled with other questions of desirability, would indicate that the best construction for immediate use in the next few years would be a welded aluminum-alloy fuselage and some type of aluminum beams with a magnesium skin. Increasing the skin gages of both the wing and fuselage can be done economically without much increase of weight if the proper structural design is used.

According to Dr. Hanawalt, in aircraft wheels the main needs are lightness, toughness and high fatigue strength in this complex shape best adapted to casting. One could make even lighter wheels, or tougher or longer-lived wheels, but when all of these properties are needed, the optimum combination is best provided by magnesium. It is also the cheapest material for attaining these three attributes.

Light Weight as a Cost Factor: Trucks

Take the trucks used by Henry J. Kaiser to carry magnesium oxide between plants. Though a pair of trucks cost $4000 more than if made of steel, the difference was made up in 128 days because of bigger pay load. Kaiser has continued this idea and has built an all-magnesium truck train that hauls a pay load of 6000 lb. more than conventional steel units of the same type.

The truck train is used by the Permanente Cement Co. It is a 60-ft. unit, consisting of a semi-trailer and trailer pulled by a 1946 Peterbilt tractor, powered by a 150-h.p. Cummins diesel engine. It has a possible pay load of 51,230 lb. as against 45,310 lb. for the lightest of similar steel units. Aircraft principles of monocoque construction are used. High strength magnesium alloy was used for the entire body, ladders, hatch covers, dumping mechanisms, doors, handles, hub and spokes of gears.

Sheets, ⅛- to ¼-in. thick, are protected with clear lacquer. The side plates of the body act as load-carrying members, thus eliminating the conventional frame. The carrier will haul an additional pay load of 16 barrels of cement (6,016 lb.) at decreased operating costs without placing an extra burden on state highways. A fleet of six of the magnesium units on a monthly 8000-mile run, one-half of which would be payload, would haul 864,000 more payload tons per mile in one year than steel units. Also, there will be longer tire life, savings in fuel consumption, longer body life, faster hauls and better roadability due to the low center of gravity of the unit.

Kaiser has compiled savings in dollars and cents from using a magnesium train for this particular cement company application and run. For every 1000 lb. the company takes off its train tare weight, assuming capacity for carrying is not lessened, the company saves $643.20 per year; for every 5 tons taken off the tare weight, the saving is $6,431 per year. And for every additional investment of $1,000 on magnesium over steel in truck train construction, it takes 3.11 months to "pay off." (After that period the company starts making money on its cheaper transportation.)

The Purity Baking Co., Charleston, W. Va., is using standard magnesium truck body shapes and sheet. The body weight, including interior tray racks to hold 2150 loaves of bread, is 1060 lb. in magnesium as against 2300 lb. previously in steel. This cut gasoline consumption 3 to 4 gal. over each typical delivery run of 125 miles. It also reduces wear on tires and

chassis and promotes easier handling on the highway, in this case over hilly country with about 45 stops per 125 miles. When the company's entire fleet is equipped with magnesium, saving in gasoline alone will be $1,000 per month.

Other Economical Applications

Scores of other examples can be given to show the economy of magnesium. A stadium chair is rented to sports lovers at, say, 25 cents, to provide a comfortable backrest in the concrete stadium. These chairs were originally made of iron rod, welded together and painted. But the newer stadium chair is made of magnesium and fastened by amateurs by riveting instead of welding. Four new chairs weigh but little more than one former chair and the magnesium chair does not cost "appreciably" more than the iron seat.

Pratt, Read & Co., Ivoryton, Conn., makes piano actions, 42 in. long, consisting of separate units which operate from a rail running longitudinally with the keyboard. Each unit actuates the hammer when it is operated by the key movement. The fabrication of these rails has been one of the greatest headaches in the piano industry. One rail, which is L shaped and about 1 in. by 1½ in., has some 270 holes. When the action mechanism is fastened to the rail by means of screws, one has 270 wedges which tend to split and warp the rail. When this occurs, the piano action becomes inoperative. Magnesium has met this difficulty perfectly. It extrudes satisfactorily and drills and cuts as easily as the wood but does not have the warping and splitting characteristics of wood.

While the first cost is higher, the maker is convinced that due to 100% recovery of the magnesium rails final cost is much lower. There is another advantage in that in wood the company must use the highest grade possible, kiln dried down to a low moisture content, and then shape the rail to hold the small parts. It is very difficult to make identical runs of rails in wood.

The Wilson Sporting Goods Go., Chicago, promotes a catcher's mask, changed in material and design from its previous mask. The newer mask of magnesium has better visibility and 50% weight reduction, or from 42 oz. to 21 oz. The magnesium mask sells for $9.00; the one of aluminum, for $10.50.

The Penhaligen Peel Co., Midland, Mich., redesigned a bakers' peel of magnesium to replace the conventional wooden peel. Though the magnesium peel retailed at $6.25 as against 80¢ for the wood, the newer peel outlasted 40 wooden peels, thus virtually reducing the magnesium tool to 20 cents. The magnesium peel has been used since 1932, with no records of failure. The magnesium peel is guaranteed for a year, the wooden ones lasting a week or ten days.

The conventional wooden hod carrier weighs 12 lb., as against 4 lb. for the newer magnesium carrier. But the wooden hod absorbs moisture and cracks and splinters, even when reinforced with steel straps. A steel hod, when of heavy enough gage to make for rigidity, is a back-breaker. The magnesium hod carries about 8 lb. more plaster and makes for fewer trips and less labor. Though costing more originally, the magnesium carrier will save itself on one large project or in one season. During recent tests a workman remarked: "You're not foolin' me, mister. The boss gives me a hod 8 lb. lighter, then puts 8 lb. more plaster in it so I'm carryin' the same load goin', but 8 lb. less coming back empty. So I'm goin' to hang onto this."

In the printing industry there is a new magnesium engraving plate, replacing brass and zinc. Not only is magnesium light in weight and easy to machine, but metal prices, on a volume basis, are cheaper. Thus, the relative cost per pound on an equal volume basis a few months ago were: magnesium, 100%; zinc, 106%; and brass, 211%. Since then zinc and brass prices have risen, making the magnesium even cheaper.

What of the Future?

Leo B. Grant, sales manager, Dow, told a U. S. Senate Committee that the cost of magnesium in the next two years will go down more as a result of technological advances than as a result of production quantity. (But the second is an important factor to reckon with.)

Ted Atkins, director, Magnesium Assn., has stated that the cost of magnesium in the pure ingot stage will be reduced, not only because of by-products (chlorine, iodine, calcium, sodium, salts, etc.) but because of improved methods of production.

Magnesium will also be found economical when parts are redesigned to make for less volume per part. Thus, steel stampings forged ahead some 20 years ago when parts were redesigned to fit stampings which proved lighter, stronger and lower in cost than parts they replaced. Recently a cover for an adding machine, originally designed in ⅛-in. thick aluminum, was redesigned, 0.051-in. thick for magnesium. (The designer said 0.040 in. would have sufficed.)

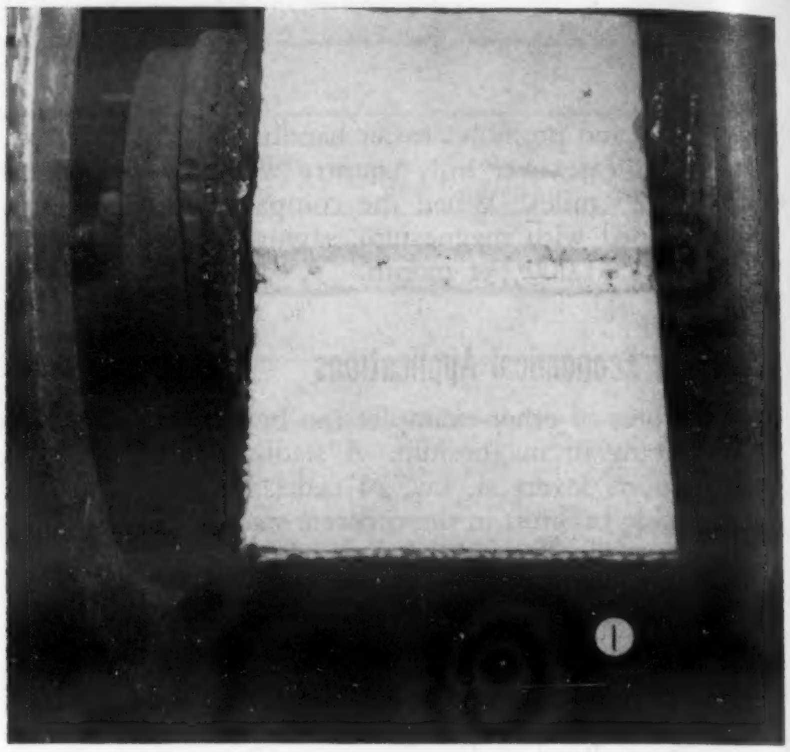
Again, magnesium is one of nine minerals or metals, plentiful enough in supply to last through the twentieth century, the other metals among the nine being iron and molybdenum.

Mr. Dow, himself, prophesied to the Senate Committee that production costs should decrease, maybe as much as 5% per year for 5 years. It is only a matter of time before magnesium sells as cheaply as aluminum on a *per pound* basis and thereupon sells much cheaper on a *volume* basis. The power required in the electric cells in Texas averages 8½ kw. per lb. of magnesium produced. Every reduction in power cost by 1 mil per kw. makes magnesium 1¢ per lb. cheaper to produce.

Admiral Cochrane of the U. S. Navy said recently that it is only a matter of time before magnesium alloys can be used where aluminum now is for further weight savings in naval vessels.

Finally, new processes or revived old processes may further improve magnesium and make it more highly competitive. Recently released from secret archives, for instance, were many case histories on shot-peening magnesium which improved its physicals and presumably allowed use of smaller volume per part or component. And that's another story!

Magnetic powders can be used to locate sub-surface flaws in welds, sheet steel and thin castings through the use of superimposed electrical fields.



Vector Fields to Locate Deep-Seated Defects in Steel

by ROBERT M. KILLEN, *La Plant Choate Mfg. Co.*

USE OF MAGNETIC POWDERS to locate discontinuities in steel castings and weldments is a well-established inspection procedure. Like all test methods, it is of value only when used with its limitations clearly in mind, and with an adequate understanding of its method of functioning. The relationship between the strength of the magnetic field set up, the size of the discontinuities, and their depth must be borne in mind for proper interpretation of test results.

As ordinarily used, magnetic powder inspections by the Magnaflux method will locate discontinuities to about ¾ in. below the surface of the metal. This is adequate for detection of cracks in welds, slag inclusions, etc., in weldments; for locating slag stringers in thin steel sheets; and for indicating most defects causing discontinuities in thin sections of steel castings.

With thick sections, use of higher wattages is helpful, the heavier magnetizing current thus producing a stronger flux in the work. A perceptible pattern can then be obtained when defects are located below the range at which irregularities in the lines of force are ordinarily indicated at the metal surface.

A second method of indicating subsurface defects located below the usual depths consists of creating a vector field in the piece. An alternating current is used to create a field superimposed on a direct current field, and a resulting combination of strong and weak fields of controlled direction. The theory underlying the action of the vector field has yet to be propounded; the method is still empirical, and the technique is largely trial and error, but results obtained show the worth of the method.

To use the vector field for magnetic powder inspection of welds in thick sections, the piece is first magnetized in the usual way, with the field formed at right angles to the direction of the weld bead. An alternating current is then applied, with its intensity held below the point at which demagnitization would occur. The direction of application of the a.c. is a matter for trial and error, but it will be somewhere between 45 and 90 F to the direction of the stronger d.c. field. The intensity of the a.c. field is likewise determined only by repeated trials.

Best results at the La Plant Choate Mfg. Co. have been obtained with the weak field oriented to just less than 90 F to the strong field. The alternating current was held to about three-fourths of that used for the strong field. These conditions produced the maximum indication with the work being studied, which was 4-in. steel plate, welded to a butt joint.

2

To illustrate the operation of the vector field method of inspection, a test plate was made up with an intentional subsurface defect. In Fig. 1 the plate is being examined with magnetic powder by the conventional direct current method of magnetization, using 2500 amp. Only a small surface rupture is made visible. In Fig. 2 the same plate is subjected to direct current magnetization as before, using 2500 amp., and then an alternating current field is superposed by the use of prods connected to an alternating current welding generator. The alternating current used was 500 amp. The subsurface crack is indicated by the surface pattern shown.

All examinations were made by the dry powder method, and there was reason to believe that the procedure would not be effective with the wet method.

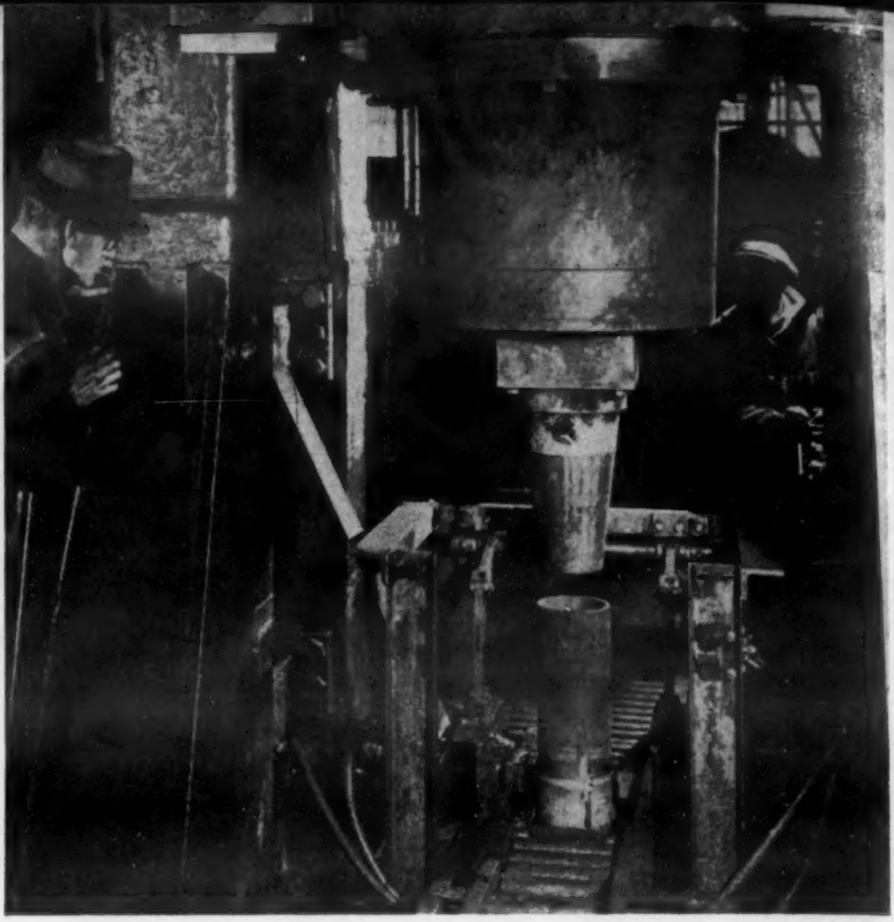
The equipment can easily be adapted from the standard Magnaflux apparatus. The solenoid coil on the machine is used to set up the strong field. A rheostat is then connected in series with the demagnetizer, and the current to the demagnetizer is slightly reduced. The direction of this a.c. field is controlled by positioning of the prods, and, with its input so limited that demagnetization will not occur, the weak field is induced in strength and direction fixed upon as giving best results. The powder is then applied in the usual way, and the pattern studied.

If for any reason it is not practicable to connect a rheostat into the demagnetizing circuit, an a.c. welder may be used for setting up the weak field. The most desirable values of field intensity may be more difficult to determine in this case, however.

The apparatus as described was used at the La Plant Choate works for setting up procedure in the welding of 4-in. plate. It was found that a definite indication could be obtained with slag stringers in the plate at the weld at depths of half the plate thickness. In this case any slag stringers in the plate would be at right angles to the axis of the weld bead, and would not be indicated by the field in which the defects in the bead itself would be most clearly shown.

After welding procedure had been fixed upon for this job, using the vector field to locate defects, only the usual magnetic powder inspections were made in routine inspection of production. As a result, the possibilities and limitations of the vector field were not explored as fully as the preliminary results would seem to warrant. The method awaits more elaborate study of the techniques and results, and formulation of a theory that will aid in fixing its field of usefulness.

1. The reduced tube, cut to length, is upset at one end to form the head of the housing.



2. Flaring of the bottom of the tube takes place in a heavy press.

Steel Tubing and Plate Replaces Castings in Heavy-Duty Parts

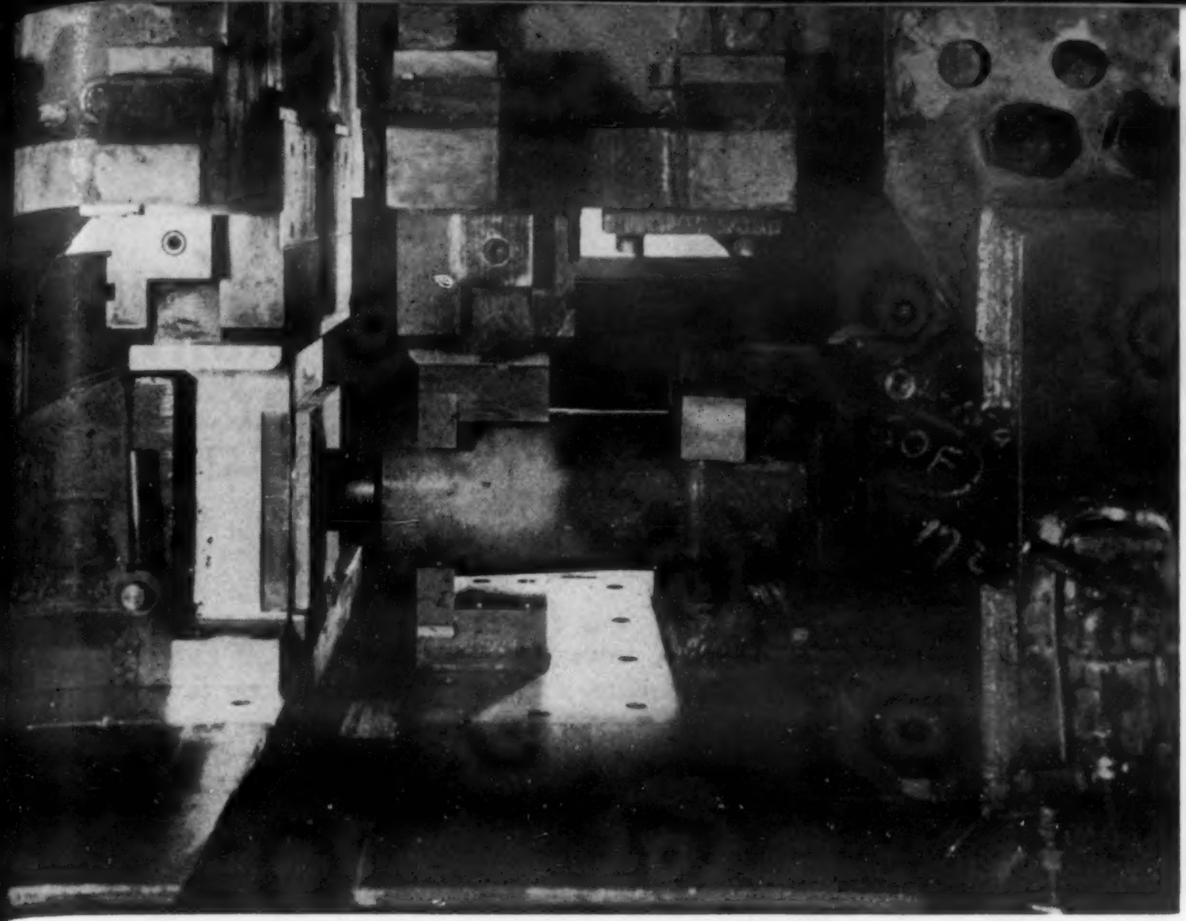
by KENNETH ROSE, *Engineering Editor,* MATERIALS & METHODS

Forming and welding are combined to produce parts for tough railroad services that are light in weight and free from hidden defects.

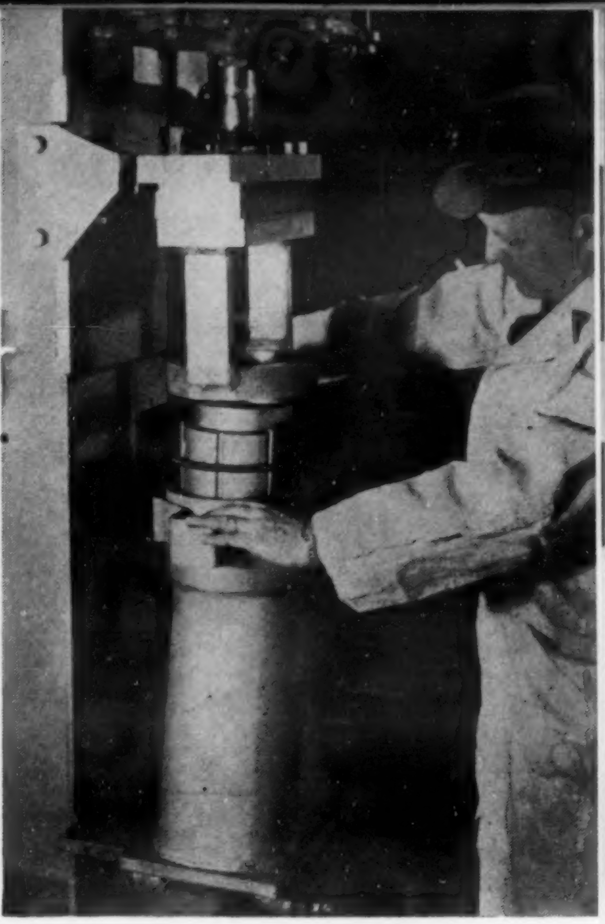
WHILE THE RAILROADS OF THE COUNTRY have been quite ready to adapt the bodies of both freight and passenger cars to the latest ideas, they have been much more reluctant to change anything about the underbody. There are several good reasons for this. One is that, from accounting and tax considerations, it is the practice of most railroads to rebuild cars from the trucks up, whenever practicable, rather than to buy new capital equipment. Another is that interchangeability is one of the most important advantages of cars on the railroads of the United States and Canada, and this in itself imposes limitations upon change. A third is that the heavy cast steel parts so generally used have proved themselves over many years of service, and the railroad engineers, mindful of their responsibility for the lives of passengers and the safety of freight, are not willing to change materials or design until the newcomer has been adequately proved in tests and in trial service.

Draft gears have been made of heavy steel forgings or castings, in keeping with the remainder of the railway car substructure. Recently a draft gear made by forming and welding has been approved by the Association of American Railroads. It is being manufactured by the Railroad Products Div. of the A. O. Smith Corp., and will be marketed by the Hulson Co. of Keokuk, Iowa, and Chicago.

The new draft gear is the first to be made by forming and welding, and is also the lightest ever to re-



3. **The formed tube is flash-welded to the base plate to complete the housing.**



4. **A small spring holds the shoes in place as the parts are assembled in a press.**

5. **A breaking-in substitutes for machining to smooth surfaces in contact. The breaking-in process is controlled by recording the increased friction as the surfaces meet more accurately.**

6. An exploded view of the draft gear, and the gear assembled.

ceive A.A.R. approval. It weighs only 202 lb., which is less than half the average weight of draft gears. It is estimated that this weight saving will be about 400 lb. per car, and at that figure will save about 12½ tons in a freight train of 100 cars.

In fabricating the draft gear, an abrasion-resistant steel is used that closely approximates the composition SAE 1340. A special steel tube is made in the company's pipe mill in 40-ft. lengths. The tube is made in 10¾-in. outside dia., and the first operation is the hot reduction of the tube to 7⅝ in., with a wall thickness of 7/16 in. The tube is then cut to the proper lengths for fabricating into the draft gear housing.

Using induction heating the tubes are heated to 2100 F at one end, and, held by a porter bar, are upset to form the head of the tubular section. Two pieces of formed strip steel are flash-welded together to form a guide support, and this is slipped over the tubular section to the upset portion. Four studs are welded in place to support this guide, using the submerged arc process. Unionmelt machines are specially mounted to secure a deep weld with these steel parts.

Operations on the opposite end of the tube start with the heating of the tube to about 2100 F by induction heating equipment. It is then placed in a press, hot end up, and a flaring die gives the tube a conical form. A second flaring operation follows, in which the housing is expanded to an oblong shape at the hot end of the piece.

The housing now has the form of a tapered hollow shell, rounded at the top and flaring out to an oblong cross-section at the bottom. A rectangular base plate at the flared end completes the housing, and in preparation for welding this base plate in place, a boss is welded to the base plate. This boss, threaded, serves as the means of fastening the retainer bolt that holds the spring and friction mechanism in place. The base plate is then placed in a flash welder in a vertical position, and the tubular portion is clamped in the welder in dies that automatically position it in relation to the base plate. The welding of the two parts takes place without any necessity for trimming the tubular section, due to close control of all the tube forming operations. An annealing and stress relieving treatment follows, and the housing is completed.

An inner and an outer spring are placed inside the housing in the final assembly, and a retainer bolt runs through the plunger and the springs to hold the assembly together. Positioned around the plunger are four shoes, held in place by a positioning ring and a spacing ring, and shaped so as to rub against the housing and the plunger. The assembly is completed in a press that compresses the springs and permits the placing of the retainer bolt.

The plunger is made in the Smith plant in a 9000-ton press, the entire forming operation being completed from bar stock in one pass.

One of the most interesting operations of the series is the "wearing-in" process. All of the parts in the assembly have been rough forgings except the threaded retainer bolt. To obtain the proper contact between the housing and the shoes so that the draft gear will have sufficient frictional capacity, the assembled gear is placed in a 1500-ton press equipped with special gears to permit working the plunger and shoes up and down in the housing at the rate of about 48 times per min. Strain gages placed outside the housing are connected with an oscillograph, and the amount of frictional resistance built up as the shoes are worn into more uniform contact with the housing is measured on the screen.

Certification by the A.A.R. is for interchange on the railroads of the United States and Canada. Approval was granted after six pieces, selected at random from a lot of 50 draft gears, were tested at the A.A.R. test laboratories at Purdue University.

The price of the new gear is in the same range as those now in use. Advantages are expected to accrue from the lighter weight, and from the greater freedom from possibility of hidden defects. This latter is the result of using rolled steel, which can be inspected before fabrication and use.

When and How to Use Cast Iron

by T. E. EAGAN, *Chief Metallurgist, Cooper-Bessemer Corp.*

THE GRAY IRON OF TODAY is a great deal different from the gray iron we knew some 20 years ago. It is no longer a material that could be used only for its castability and its cheapness with very low tensile strength and extreme brittleness. Metallurgists have improved gray iron quality to the point that it is an engineering material which, if properly applied, will give outstanding performance. Gray iron can be very broadly called steel plus graphite.

The graphite occupies 11.00 to 17.00% of the volume of the metal, depending on the analysis and the cooling rate of the casting, and controls to a large extent its physical characteristics. If we could put all of the graphite in a ball and locate it in one spot in the center of a casting, it would have little effect on the strength. However, if it were put as a slab across the piece we would have no strength whatsoever. Therefore, by controlling the distribution of the graphite and its amount, gray iron of various strengths can be produced. The different ways to distribute graphite have been studied quite thoroughly and are published by the A.S.T.M. as Specification A247-41T.

The matrix metal will have the tensile strength of steel which has the same analysis and microstructure. This may vary from pure iron or almost a pure iron with a tensile strength of around 40,000 psi. to a pearlitic steel as shown before with a tensile strength of 120,000 psi. By controlling the distribution, size and amount of the graphite flakes, tensile strengths between 10,000 and 60,000 psi. can be produced.

Tensile Strength

Due to the fact that the tensile strength of gray iron indicates to a certain extent the other properties desired, the general rule has been to specify it as the controlling criterion for the purchase of castings. This is done mostly by using A.S.T.M. specification A-48, which gives the various classes of gray iron normally available. The tensile strength thus designated is taken from a separately cast test bar not attached to the casting, and various sizes of these test bars are used, depending on the section thickness of these castings. Table I gives a summary of the specification.

This article is based on a talk presented by Mr. Eagan before a joint meeting of the American Society of Tool Engineers and American Foundrymen's Association.

The quality and physical characteristics of present day gray iron make it an engineering material which is selected for its ability to do a job, rather than only because of cheapness, as was once the case.

Table I

Class	Tensile Strength, Min. Psi.	Usual Min. Wall Thickness, In.
No. 20	20,000	1/8
No. 25	25,000	1/8
No. 30	30,000	1/4
No. 35	35,000	3/8
No. 40	40,000	1/2
No. 50	50,000	1/2
No. 60	60,000	3/4

Size of Section, In.	Nominal Dia. of Test Bar, In.
0.50 and under	0.875
0.51 to 1.00	1.20
1.01 to 2.00	2.00
over 2.00	Larger bars by agreement between manufacturer and purchaser.

Why have seven different classes of gray iron? In the first place, the lower the class of iron designated the cheaper it is. Thus, the problem of economy enters into it. Secondly, the higher classes of iron are difficult to cast into thin sections. Table I indicates the usual minimum sections that can be economically used; however, they are not mandatory. Should sections thinner than are indicated be desired, consult a foundryman to see if the casting design is such as to permit gating to allow iron to flow through the thin sections.

Section thickness has a great deal to do with the tensile properties obtained in any casting. The upper part of Fig. 2 indicates to a large extent what happens to tensile strength as section thickness increases or decreases from the size of the arbitration bar used. The slope of these curves is rather steep as section size is changed in the thinner sections, but as the size of section is increased they tend to flatten out so that in these thicker sections there is less change. There is also a tendency for the higher class of cast irons to show less drop in tensile strength than the lower class material.

The fundamental thing that controls tensile strength of the material in any gray iron casting is the rate at which it cools from the molten metal down to a temperature around 1000 F. It can be definitely stated that for any given analysis of material the tensile strength obtained in the casting is a function of its cooling rate.

Unfortunately, there is not a great deal we can do

Fig. 1—Shown here is the microstructure of a good grade of gray iron. The gray streaks are graphite and the finger-print like material is that found in a piece of 0.90 carbon steel. (Magnification 250 X, etched with Pecial plus HC1.)

about the cooling rate of any given casting because these are primarily controlled by the design of the casting, the size of the flask used, the method of gating, and the sand used, etc. These are pretty well fixed by the foundry practice required to produce sound castings. Therefore, to obtain any required tensile strength we must control the chemical analysis. It is entirely possible to do this. The practical aspects of the methods used are very complicated and require a considerable knowledge of the metallurgy of gray iron; however, it is being done daily with success. If you need a certain tensile strength in your casting, it is usually possible for the foundryman to give what you desire if you are willing to cooperate with him on the design.

Other Physical Characteristics

Yield Point: In design work it is usual to avoid stresses higher than the yield point of the material if the material is to be subjected to static loading. The yield point of gray iron is close to the tensile strength, thus it is possible to use the material at higher stresses. Fig. 4 shows the comparative yield strength of some of the cast ferrous alloys. It can be seen that the yield point of gray iron is comparable to that of low carbon cast steel.

Compression Strength: One of the outstanding characteristics of gray iron is its compression strength. In fact, in compression gray iron is much stronger than steel. Fig. 5 will give you an idea as to this quality of gray iron. It will be noted that gray iron in all classes is much stronger than cast steel when used in compression.

Modulus of Elasticity: In design work the modulus of elasticity is an important factor in most calculations. The modulus of elasticity of gray iron runs somewhere between 12 million and 22 million psi., depending on the tensile strength, the amount and distribution of the graphite, and microstructure of the matrix. However, these figures must be used with discretion because cast iron is a heterogeneous material and does not fulfill the requirements of homogeneity, isotropy, and elasticity as required by the elastic theory. In many cases cast iron behaves completely different than would be expected by the elastic theory. Shape of the section influences the stress distribution, and as the load increments are increased the neutral axis shifts and the stress distribution line follows a curve instead of a straight line, such as is found in a homogeneous material such as steel.

Endurance Limit: Parts subjected to dynamic forces are usually designed so that the stresses imposed are below the endurance or fatigue limit. In gray iron the theoretical endurance limit is between 35 and 50% of the tensile strength. The 35% applies to a very large section whereas the 50% would apply to smaller sections which are comparable in cooling rate of the 1.2-in. arbitration bar. For most sections an arbitrary figure of 40% of the tensile strength can be safely used. The use of the theoretical endurance limit is subject to modification because of design and service requirements. This is true of any material. Let us consider one or two of the factors as they affect gray iron.

Notch Sensitivity: Gray iron is much less notch sensitive than steel. This is amply illustrated in Fig. 6, which shows the endurance limit in reverse bending of steel unnotched and notched as shown. The steel was a S.A.E. 1040 steel heat treated to 80,000 psi. tensile strength. The tensile strength of the gray iron was 49,000 psi. In the case of steel the reduction of the endurance limit caused by the notches was 50%. In the case of iron the reduction was 21%.

How does this apply to the use of cast iron? Use as an example a piece that could be made of steel or of cast iron. The steel to be used would have a tensile strength of 80,000 psi. and an endurance limit of 35,000 psi. which, because of the notches in the design, would require use of the maximum allowable stress of 17,000 psi. The cast iron has a tensile strength of 49,000 psi., an endurance limit of 16,500, but because of its non-notch sensitiveness we can use as a maximum allowable stress of 13,000 psi., which is only 4,000 psi. less than that for steel. Because of the factor of safety usually used it would be amply safe to use the cast iron in place of the steel.

This is not as a condemnation of steel nor a claim that cast gray iron will always take the place of steel. This is not true, because other service requirements may indicate that such an analysis as given above is incorrect and that cast steel or forged steel would be much better. The point to be stressed is that there are many cases where steel castings are specified where gray iron could serve just as well. In such cases the steel is misapplied.

With further reference to the notch effect of stresses, a considerable amount of relief can be effected by proper contouring. However, this contouring must be done intelligently and the use of the new SR-4 strain gages can be a great help.

Here is an example of what can be done. Fig. 7 is a cast gray iron crankshaft having a tensile strength of over 65,000 psi. The notch effect at the fillets between the webs and the pins and journals normally impose a stress concentration of over 2 to 1 for a

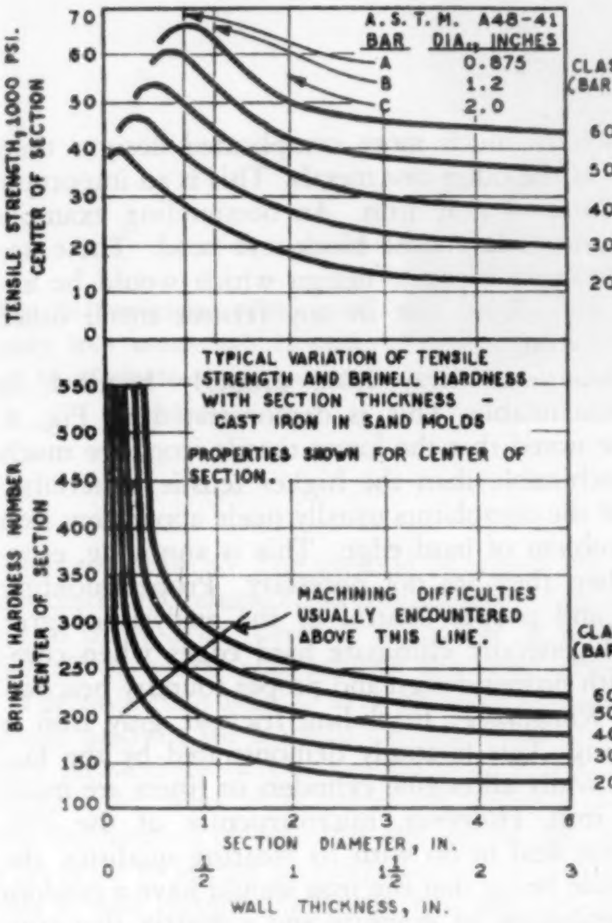


Fig. 2—Influences of section size on tensile strength and Brinell hardness. (Courtesy: American Foundrymen's Association.)

forged steel shaft and 1.75 to 1.00 for this high tensile iron. However, by contouring as shown the stress concentration is almost completely eliminated. Shape of the contour was determined by the use of SR-4 strain gages. It can be readily appreciated that such contouring is only practical in a cast shaft as it is almost impossible to machine such a contour economically.

Service Characteristics

Damping Capacity: Under dynamic operation many failures of parts are caused by the surge of vibration that may be set up in the piece due to the dynamic forces. This is amply brought out, of course, in the critical vibration experienced in crankshafts in internal combustion engines. This critical vibration can and does, at times, break parts in operation.

Gray iron has excellent damping capacity. The lower the tensile strength of the iron the higher the damping capacity. One of the best ways to demonstrate damping capacity is the one used in many machine shops for identifying the material in a casting and that is to strike the casting. A steel casting will ring while the cast iron casting will produce nothing but a dull sound. It is difficult to apply dampening capacity to design, but it is always well to know that it is present in gray iron.

Impact and Brittleness: Gray iron is much more brittle than steel. Thus, when gray iron breaks, it breaks with a brittle fracture while steel being ductile will break with a ductile fracture. The standard impact tests, such as Izod and Charpy, show gray iron to have much lower values than steel.

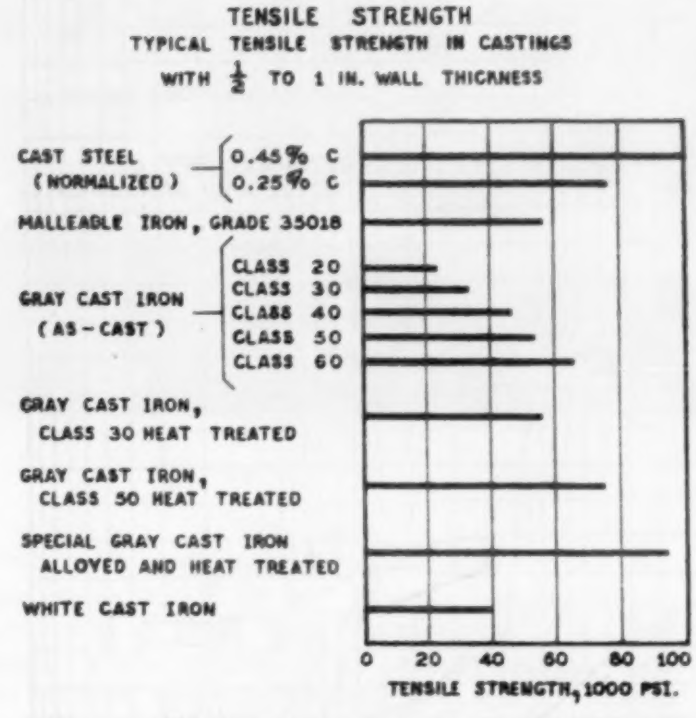


Fig. 3—Relative tensile strength of several cast irons and steels. (Courtesy: American Foundrymen's Association.)

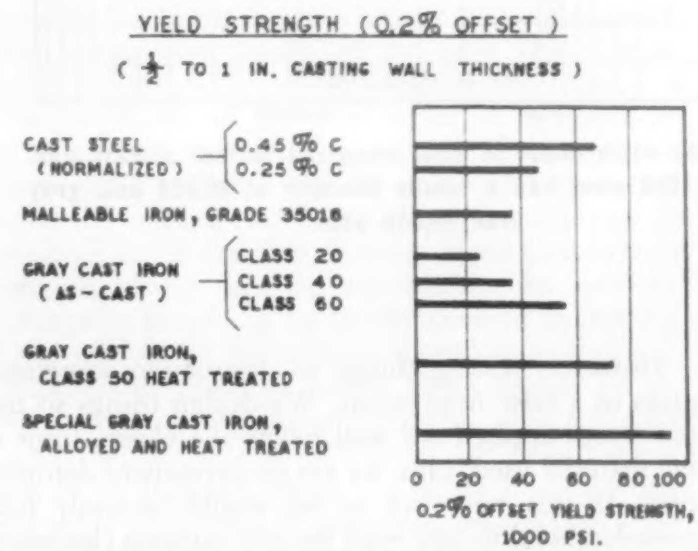


Fig. 4—Yield strength of cast irons compared to cast steel. (Courtesy: American Foundrymen's Association.)

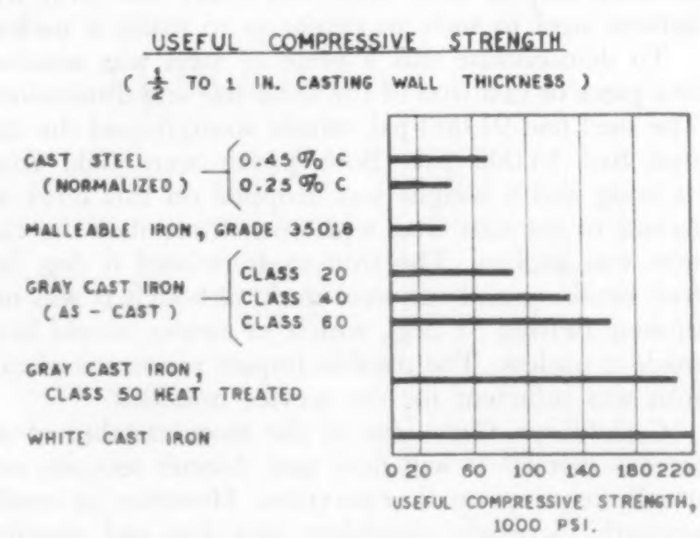


Fig. 5—Gray iron in all classes is much stronger than cast steel when used in compression. (Courtesy: American Foundrymen's Association.)

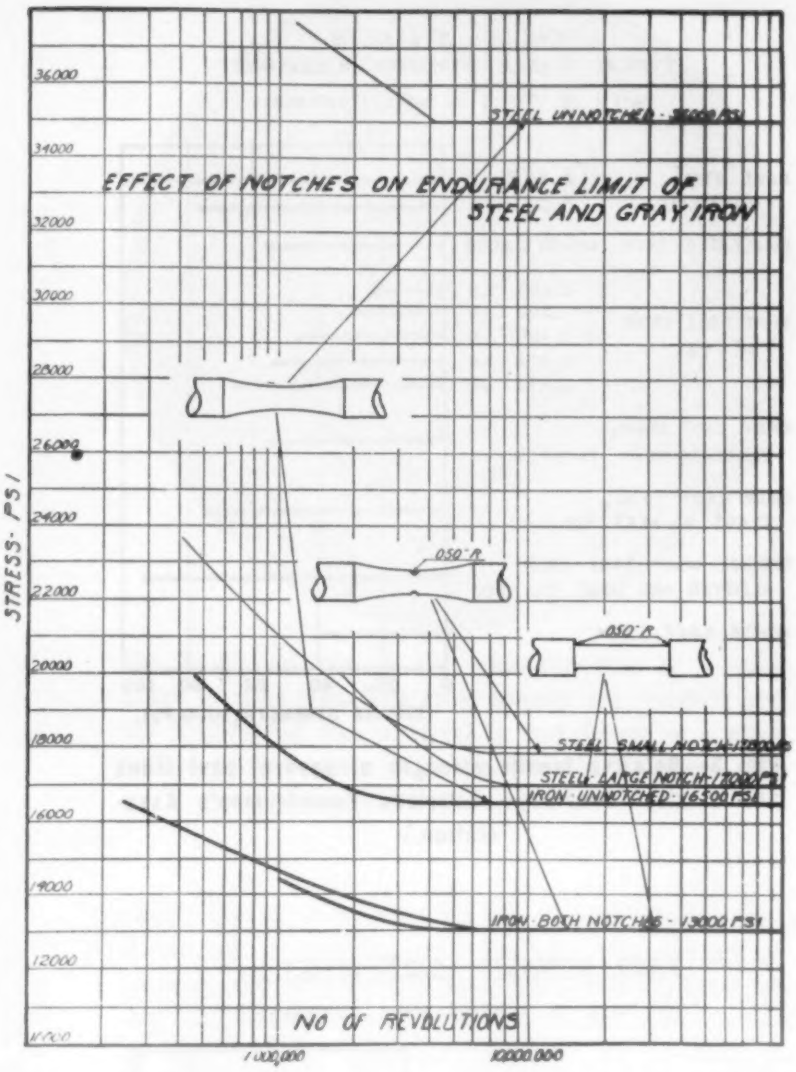


Fig. 6—The notch effect of steel compared to that of cast iron. The SAE 1040 steel had a tensile strength of 80,000 psi., gray iron 49,000 psi.

However, testing things to destruction sometimes gives us a false impression. We design things so that the forces applied are well below the elastic limit of the material used; thus, we get no permanent deformation. If this were not so we would certainly have considerable difficulty with fits and running clearances. Therefore, any amount of permanent deformation would no doubt be disastrous. Thus, the amount of deformation we get under any impact blow, below that required to fracture, is of importance. In many cases an impact blow that will break cast iron will deform steel to such an extent as to make it useless.

To demonstrate this a piece of steel was attached to a piece of cast iron of the same size and dimensions. The steel had 91,000 psi. tensile strength and the cast iron had 54,000 psi. Both pieces were held from twisting and a weight was dropped on this lever attached to the cast iron with such force that the cast iron was broken. The iron shaft twisted 6 deg. before breaking and the steel shaft, although it was not broken, twisted 35 deg., which, of course, would have made it useless. The useable impact resistance of cast iron was sufficient for the service intended.

Castability: Gray iron is the most castable of all ferrous metals. It will flow into thinner sections and usually requires small or no risers. However, as tensile strength increases, castability gets less and requires more risers and an approach to steel casting practice in molding. This is an important consideration when intricate designs are involved. Gray iron therefore lends itself to much more complicated designs than do many of the other cast metals. This is an important characteristic of gray iron. An outstanding example is the automobile engine block and head. These are masterpieces of intricate design which would be extremely difficult to cast in any ferrous metal other than gray iron.

Machinability: Gray iron, properly handled, is highly machinable. This is demonstrated in Fig. 8. It will be noted that the lower tensile irons are much more machinable than the higher tensile materials.

One of the complaints usually made about gray iron is the problem of hard edge. This is annoying, especially when they are not necessary. Proper molding practice and proper control of the analysis of gray iron will generally eliminate hard edges when combined with proper design and proper foundry practice.

Wear Resistance: In sliding friction, gray iron is outstanding. This is amply demonstrated by the fact that practically all engine cylinders or liners are made of gray iron. However, microstructure of the iron has a great deal to do with its wearing qualities, the general rule being that the iron should have a random flake distribution of graphite and a matrix that contains no free ferrite. To insure this a minimum Brinell hardness of 190 can be required. The type of microstructure shown in Fig. 1 will give good wear resistance.

In abrasive wear resistance gray iron also does a good job. Hardening the iron through heat treatment sometimes increases wear resistance. For extremely abrasive conditions a white or chilled alloy cast iron such as Ni-hard is usually indicated.

Corrosion Resistance: Another quality of gray iron is its good corrosion resistance. This is amply demonstrated by the fact that most water mains have been made of cast iron and there are examples of good condition after 100 years service. Cast iron heads, cylinder liners, and blocks in engines which are salt water cooled have been used for years with excellent success. However, where more vicious conditions are encountered special corrosion resistant grades are available.

Heat Resistance: Gray iron has good heat resistant qualities. This particular quality has not been exploited as much as it should be. Recently the A.S.T.M. developed a specification for the use of gray iron in pressure vessels at temperatures up to 650 F. Successful use also has been made in nonpressure vessels such as molten metal pots for temperatures above 1200 F. Gray iron does a good job. It will not, however, replace the higher alloy heat resisting steel castings where their use is actually required.

One of the complaints about gray iron is its tendency to grow when heated above 900 F. However, where this is a factor, proper alloying of iron can eliminate the tendency to a great degree.

Chemical Analysis: The chemical analysis of iron controls, to a large extent, the physical properties of the casting chiefly because there is so little that can be done to control the cooling rate of castings in the mold. It would seem logical, therefore, that the one thing that should be specified is the chemical analysis. However, this is far from the truth; in fact, it is

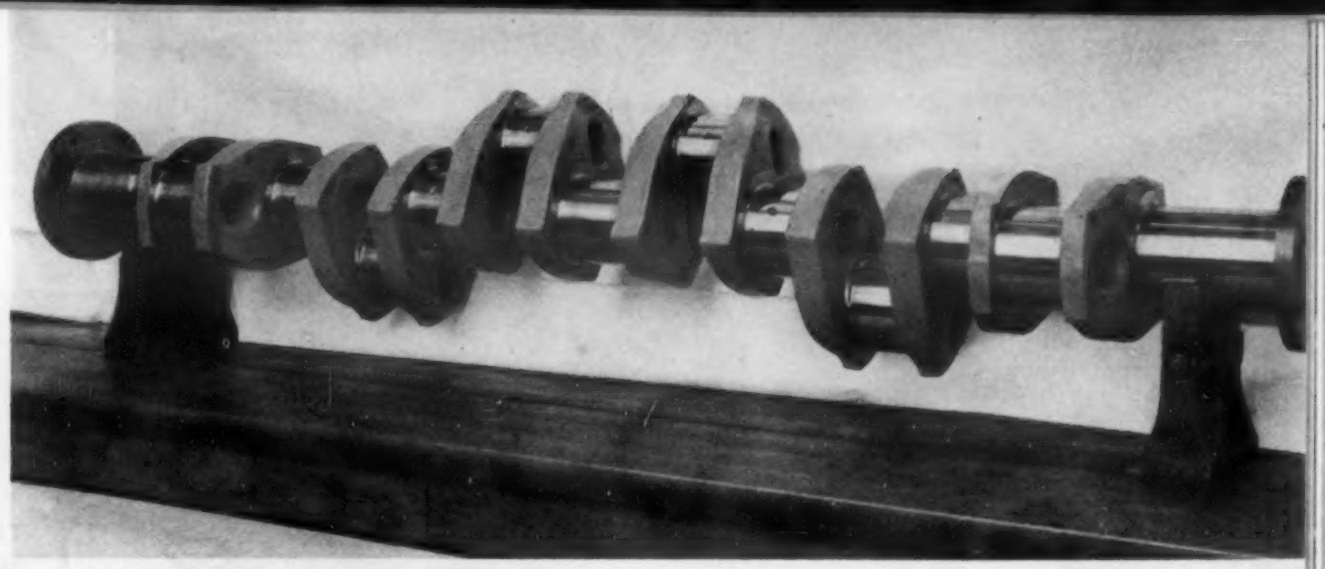


Fig. 7—Contouring of this cast gray iron crankshaft is such as to eliminate stress concentration.

dangerous to do so. The method by which the casting is poured will influence the cooling rate tremendously, and in many cases there are a number of ways to do this, all of which will achieve the same result.

The only man who is in a position to specify the proper analysis for a given casting in which the desired physical properties are specified is the foundry metallurgist, who must make his decision after he sees the method of molding, the gating, etc. Thus, it is far safer to let the foundry specify its own analysis. This is well recognized by the fact that the A.S.T.M. specifications deliberately do not specify chemical analyses. All foundrymen are perfectly willing to work to a tensile strength specification, but many will absolutely refuse to work to both tensile strength and chemical analysis.

Heat Treatment of Gray Iron

Gray iron can be heat treated the same as steel. It is possible to almost double the tensile strength by heat treatment. However, this involves a quench and tempering treatment and can only be applied to very simple shapes. Complicated shapes will crack during the quenching operation. The increase in tensile strength by heat treatment is sometimes dangerous to use because it does not proportionately increase the endurance limit of the iron; therefore, one can be greatly misled when such heat treated materials are subjected to dynamic forces.

Complicated castings of gray iron, especially those in the range of 40,000 to 60,000 psi., usually have a considerable amount of residual stress in them. Thus, in subsequent machining they are likely to distort. Stresses can safely be removed by a stress-relief anneal. This process consists of very slowly heating the casting to about 1000 to 1050 F, holding it there for about 1 hr. per in. of heaviest section, and cooling it slowly.

It has been believed for years that the best way to relieve casting stresses was to set the casting out in the yard for 6 months to a year. Experiments have shown that this does not relieve stresses. What has happened in those cases which have shown less distortion in machining after such a treatment is that the stresses being more or less concentrated on the surface have been relieved because the surface has rusted sufficiently to remove some of the metal on the surface, thus relieving the stresses. It is a much more economical and a much better practice to give the castings a stress-relief anneal.

Gray iron can also be hardened by quenching and drawing. The maximum hardness that can be obtained is about 550 to 600 Brinell. This hardening treatment is of great value for certain services. For instance, where abrasive wear is encountered, such as in machine tool ways, certain dies, and sometimes Diesel engine liners, the parts are hardened. Any of the usual methods of hardening can be employed, plus austempering, martempering, flame hardening, or induction hardening.

Some use is made of a direct annealing process on certain pieces of gray iron to improve machinability. Annealing definitely lowers the physical properties of the casting and should not be used unless these physical properties are of no consequence.

The proper use of cast iron could be discussed at great length, but space will not permit. The principles of good casting design are the same for steel, cast iron, or the nonferrous metals. They are covered in great detail in the first five chapters of the Cast Metals Handbook, which can be referred to. In general, the things to avoid can be briefly covered by stating that the sections of the castings should be as uniform in thickness as possible; ample fillets should be allowed in corners; any major change in section should be taper blended instead of filleted; etc. The casting should be so designed that it can be divided into two halves without having an irregular parting line; the design should be such that the casting will solidify properly; and, from the economical point of view, it should require the simplest possible core set-up.

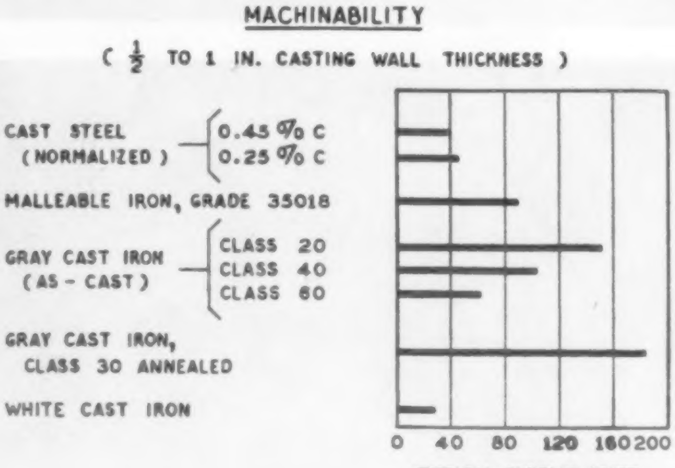
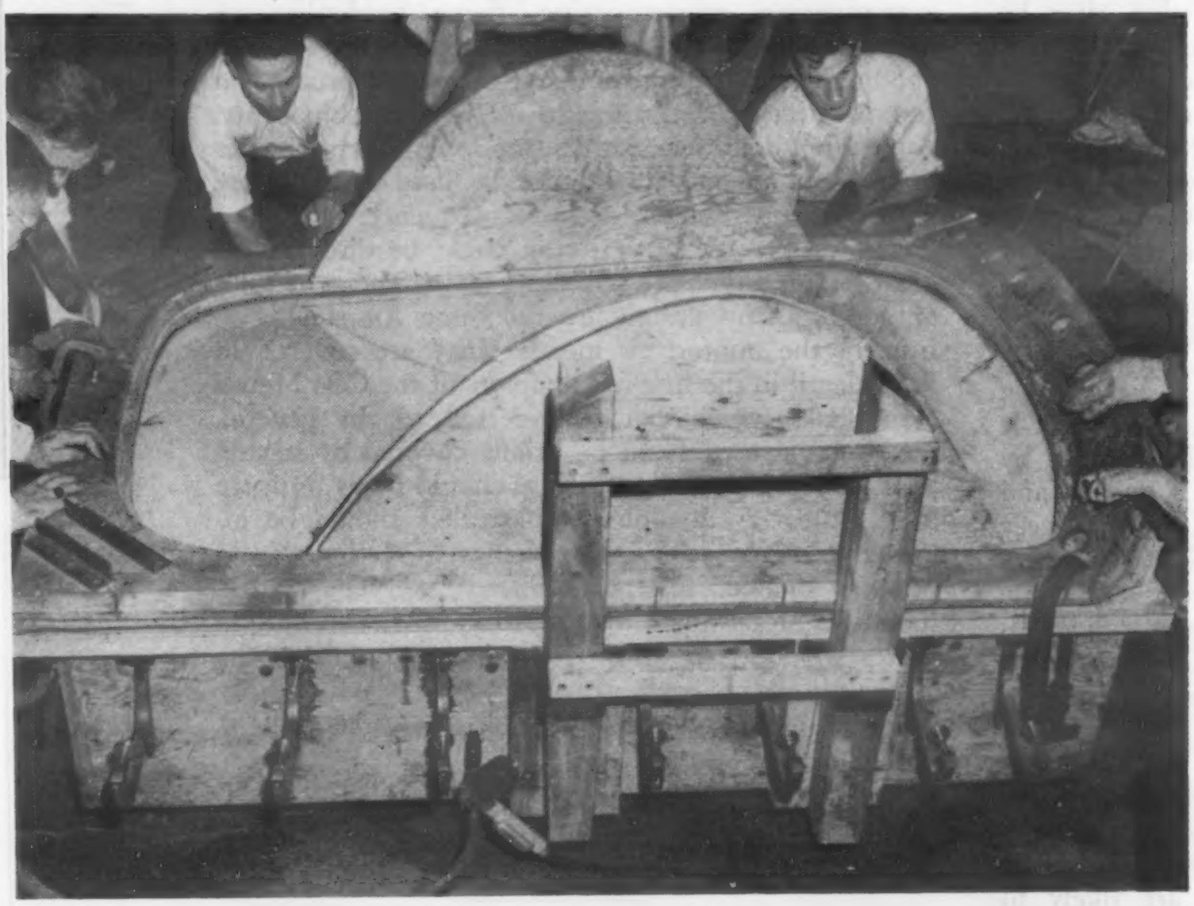


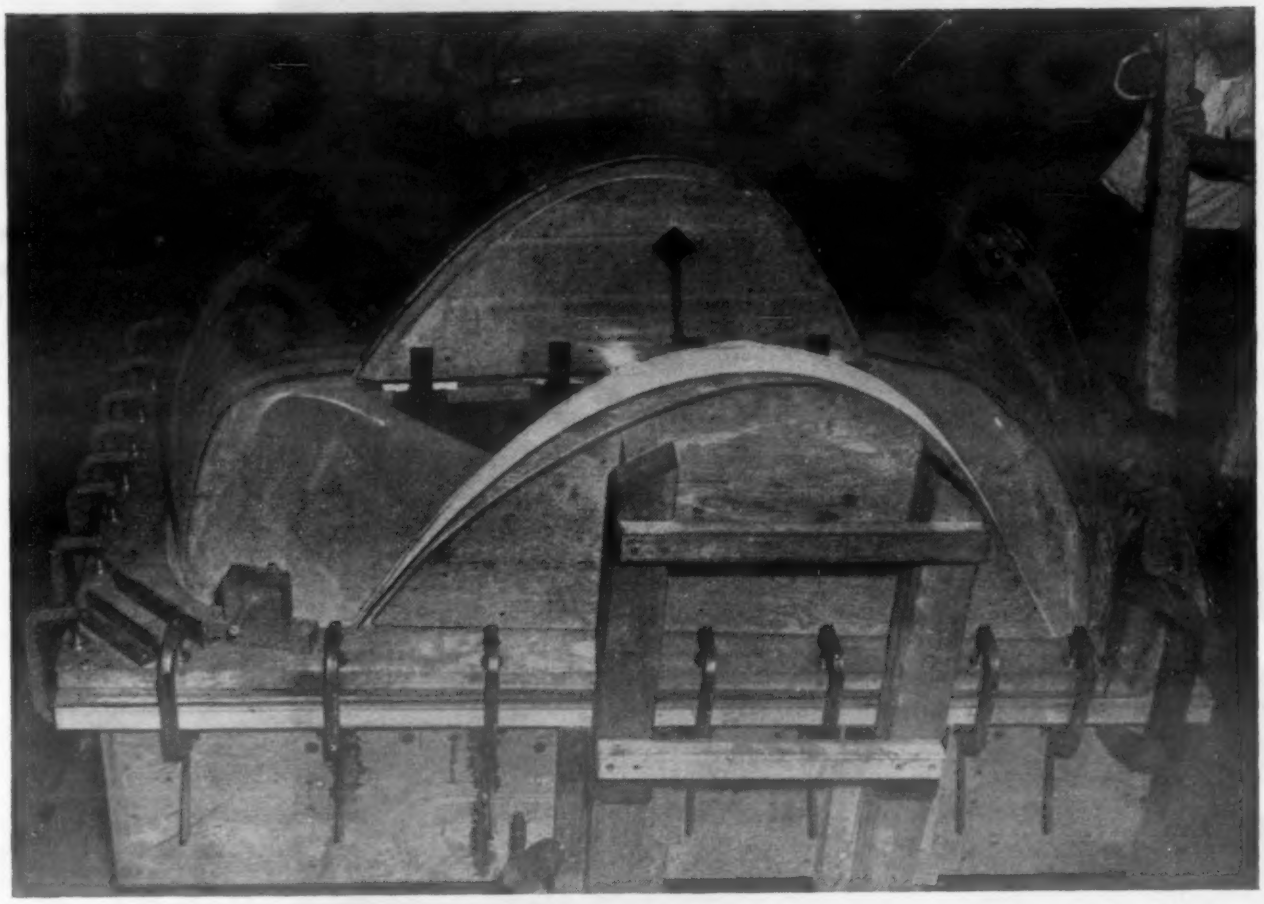
Fig. 8—A comparison of machinability of several cast ferrous materials. (Courtesy: American Foundrymen's Association.)

1 The sheet of plastic, heated to 260 F, is carried from the oven to the forming fixture on a monorail conveyor.



2 Laid flat on the fixture, a retaining ring is placed on top of the sheet and clamped with quick-acting toggle clamps. The wooden flaps that will restrain the sheet at the door opening are then put into position.

3 Air is admitted to the fixture, and the hot plastic sheet begins to expand into a "bubble".



4 As the bubble approaches full height, the inner flaps are raised inside the bubble and the hot plastic squeezed against the outside flaps, forming a flat area that will become the door opening. A toggle lever outside the fixture operates the inner flaps.

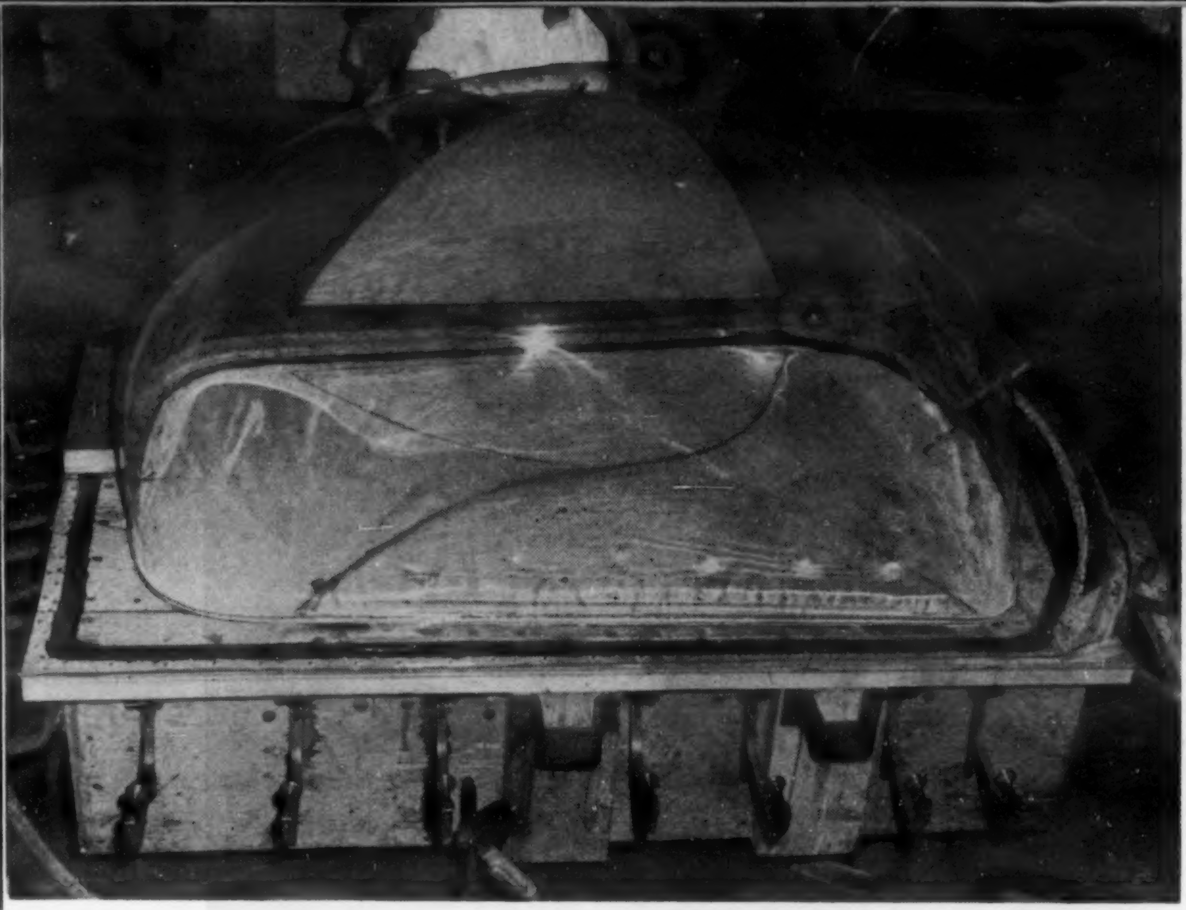
Pneumatic Forming of Acrylic Cabin Enclosures

A PICTORIAL STORY

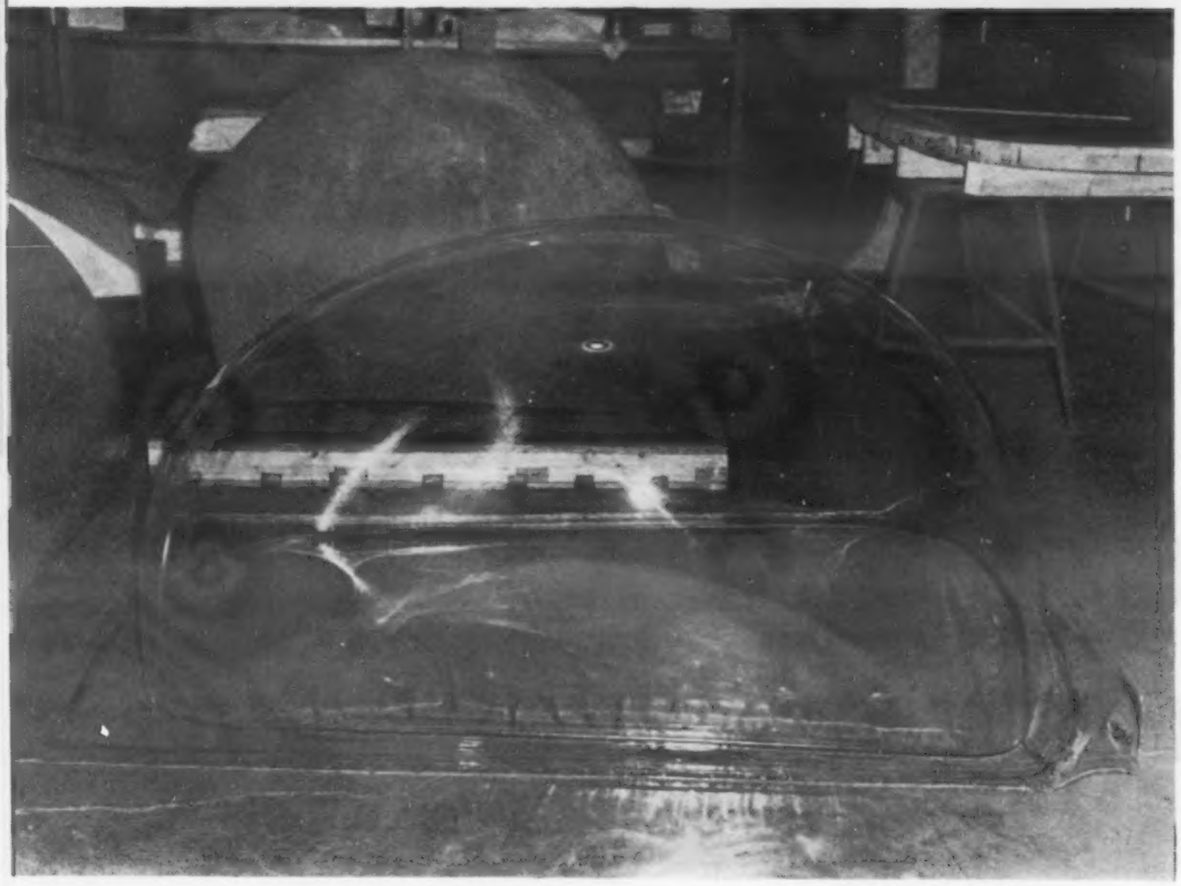
"Blowing the Bubble," under low air pressure, results in a dimensionally accurate shape being attained at a high production rate. The process also eliminates much final polishing.

THE CABINS FOR SOME MODELS of Bell Aircraft Corp.'s helicopters are enclosed in shatter-resistant clear acrylic plastic domes. The domes are required to possess good optical properties, but polishing of a molded piece of this size is regarded as too time-consuming for modern production schedules. A method has been worked out for blowing the dome to shape as a large bubble, using compressed air, and so eliminating much of the polishing of the finished form, while greatly speeding production.

A problem in the blowing of the domes is the necessary allowance for cabin doors at both sides of the helicopter. The doors are standardized, so that



5 **After reaching full height, the bubble is allowed to cool for 10 min. in the fixture with the pressure constant.**

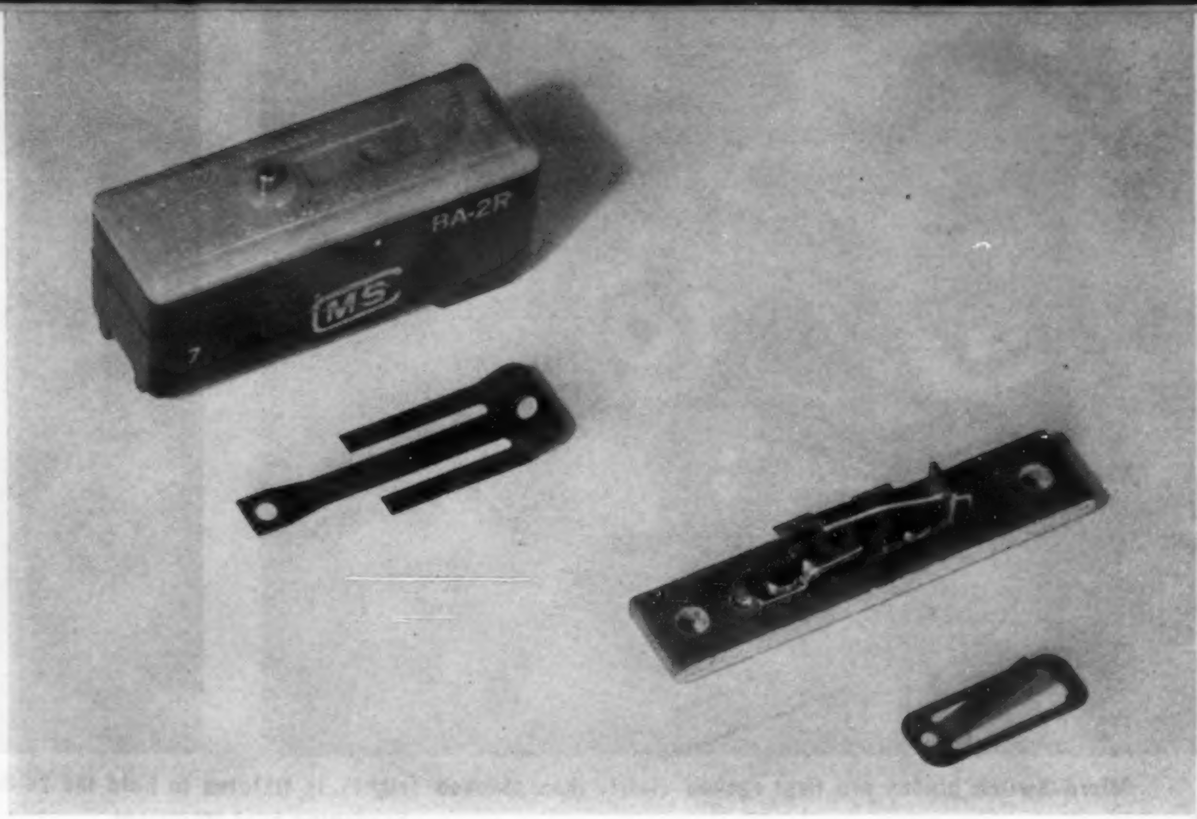


6 **The fixture is then unclamped and the dome is removed, completed except for trimming, cutting out door openings, and some polishing.**

the bubble area at these points must be dimensionally accurate to permit fitting the doors without any patch-up that would mar the optical qualities of the dome. This is accomplished by providing a pair of wooden flaps for each side of the bubble, at the door location, one wooden flap, the shape of the door, outside the bubble, the other swinging up on hinges inside the bubble to a matching position. The plastic is squeezed between these two flaps so that it becomes flattened at the door position. While the optical quality of the acrylic is spoiled at this section, it is unimportant because the door area is later cut away.

The actual forming process, called "blowing the bubble," takes place in a fixture in which air, under 2 to 5 psi. pressure, is admitted through a series of holes at the bottom of the fixture, slowly swelling the bubble. Height is checked regularly as the bubble grows, and another check is made to determine that necessary clearance for the rudder pedal is being maintained. Height is controlled by an electronic "eye" that regulates air pressure to the fixture.

A similar process is used to form the doors for the cabin enclosure. These are blown to a height of about 3 in., the convex form giving them greater rigidity, and following the contour of the cabin enclosure in general.



From the small 10-amp. open switch (right) to the heavy duty ¾-hp. switch (left) beryllium copper continues to be the lowest cost and best answer for the spring elements in all Micro Switches. Blade for the Micro Switch is blanked from beryllium copper strip 4 nos. hard. In a second operation, side legs are shaved to length and the 24-deg. angle formed.

Economies Result When Parts Are Designed for Beryllium Copper

by **ROBERT W. CARSON,** *Consulting Engineer, and* **WAYNE MARTIN,** *Consulting Metallurgist*

TO MANY ENGINEERS AND METALLURGISTS beryllium copper is a high-priced special-purpose spring material with a few spectacular uses, but "not for our equipment—we have price competition." The facts of the case are different, particularly for products where every penny counts, as the following four typical case histories demonstrate. In each case, beryllium copper provided the lowest cost answer years ago when the product was first designed; today, with recent improvements in the alloy, beryllium copper offers an even stronger case.

This story could be told many times today in components for products ranging from toy trains to accounting machines, from electric razors to jet turbines. The four examples selected to tell this story include a small snap switch blade, two springs in a fractional horsepower motor control, four springs in a lighting switch, and a diaphragm in a refrigerator thermostat. Each example was in production for several years before the War, and each one is being produced today in essentially the same form.

Beryllium copper will not give maximum economy and efficiency if it merely replaces another material—the part utilizing this alloy should be designed to take advantage of its properties.

In each of these four typical examples, as in most other successful beryllium copper applications, there are two common factors behind the success of the design: In each case the design was a new one and beryllium copper was used to its full potential. It was not a matter of substituting beryllium copper for another alloy that failed, nor was it used because it was a "little better." Each design was carefully developed to use all that beryllium copper had to offer.

One of the very earliest applications for beryllium copper—first made in 1932—came about in the development by Burgess Laboratories of a miniature quick-acting electrical switch now known as the Micro Switch. The objective was to develop a switch small enough to fit inside a room thermostat but with the capacity to directly control an oil burner motor without the use of relays. After many failures

Micro Switch blades are first racked (left), then stacked (right) in fixtures to hold the 24-deg. angle and keep the legs flat and parallel during hardening heat-treatment.

using conventional spring materials, the objective was first realized when beryllium copper was tried.

Where other materials failed beryllium copper succeeded because:

1. Its high endurance strength made it possible to crowd the necessary spring action into the required space.
2. Hardening to spring temper after forming, permitted a simple one-piece blade, simplifying design and reducing cost.
3. Much better uniformity in temper after hardening gave substantially greater precision of operation.

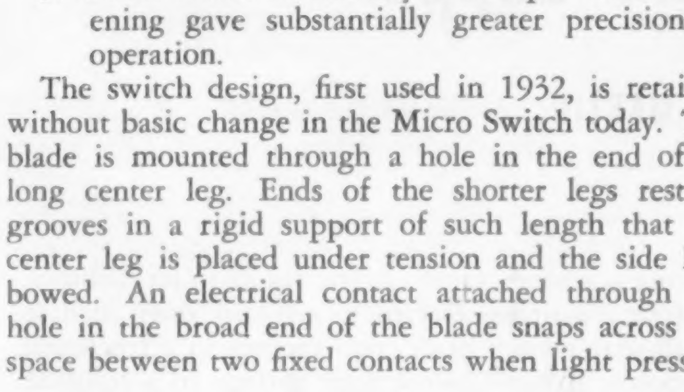
The switch design, first used in 1932, is retained without basic change in the Micro Switch today. The blade is mounted through a hole in the end of its long center leg. Ends of the shorter legs rest in grooves in a rigid support of such length that the center leg is placed under tension and the side legs bowed. An electrical contact attached through the hole in the broad end of the blade snaps across the space between two fixed contacts when light pressure is applied to the long blade a short distance from its mounted end. The switch thus consists only of the spring blade, the molded housing and a small actuating pin. Actual size of the switch is 1 15/16 in. long, 13/16 in. high and 11/16 in. wide.

Since the earliest production, the material used for this part has been 0.0085 by ⅝-in. beryllium copper strip 4 nos. hard in coils. Specifications today call for a tolerance of ± 0.0005 in. on thickness, with hardness and tensile strength after hardening in accordance with ASTM Specification B 194-46T. However, each coil of strip is inspected throughout its entire length on a special test stand. Strip is drawn by variable speed motor drive off a reel, passes between a pair of soft buffing wheels to clean both sides of the strip, and then under a dial gage indicating thickness at the center of the strip width. From there the strip is drawn past a visual inspection station where, with the aid of a mirror, the operator observes both sides. Any portion of the strip outside of thickness tolerance or having an imperfect surface is marked with blue so that spring blades made from this section of the coil can be identified and discarded later.

Blades are made in two operations: the first operation is blanking, the second a combination of bending and shaving the ends of the shorter legs. Then, after degreasing to remove die lubricant, the parts are strung on rods, racked, and loaded in heat-treating fixtures. Fixtures are closed with a screw clamp holding the nested parts under compression, and then heat treated in an air oven held at 600 F for 3 hr. After removing hardened springs from the fixture, they are spot checked for angle of bend by a gage, holding an angle tolerance of ± 1 deg.

Blades were formerly heat treated loose in a shallow screen-bottom tray, but the heat treating fixtures make it possible to hold the angle of bend to closer tolerances. This, in turn, gives greater uniformity in air-gap and travel in assembled switches, which reduces rejects and cuts manufacturing cost.

The only remaining operations are attachment of the contact, assembly in the housing, adjustment and performance testing.



In the Delco Motor control, motor current heats and expands wire A, allowing arm B to move under tension of flat spring C until switch D opens, disconnecting starting winding. Overload current causes further expansion of wire, and line contact E opens to disconnect motor. Link F assures that starting contact closes before line contact after overload.

Several other spring materials have been studied as alternates to beryllium copper, but no other material has been found that will give performance and life equal to beryllium copper without redesign. As a result, beryllium copper is being used today in every type of Micro Switch produced, from the one just described rated at ¾ h.p., 120-vo. or 100-watt a.c. lamp load, to a small open switch rated at ¼ h.p., to amp.

Back in 1937, the Engineering Department of General Motors' Delco Products Div. was given the assignment of reducing the cost of an existing household refrigerator motor control without sacrificing performance. The control had two functions: it opened the starting winding when the refrigerator motor reached normal speed, and opened the line on overload.

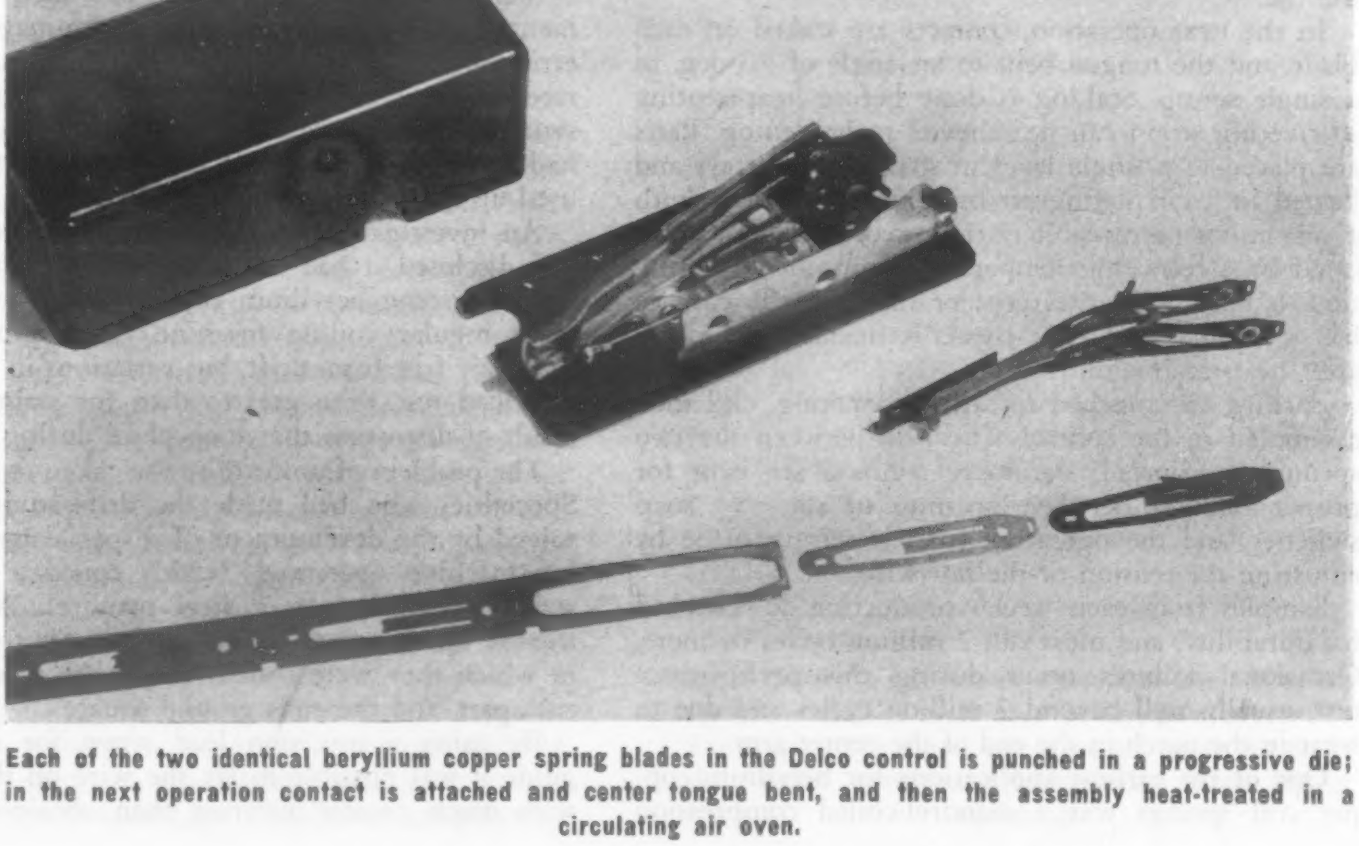
A new compact design using the linear expansion of a hot wire for the current sensitive element was developed with two independent snap action contact springs. In this design full line current is carried through the resistance wire which is heated and expands, allowing the arm to move under the action of the flat steel hinge spring staked to the arm. The hot wire element is designed to expand just enough in 1 to 5 sec. to open the top contact and disconnect the motor starting winding. Overload current causes further heating and expansion of the wire, which then opens the lower contact and disconnects the line. The relay is designed to cool at the same rate as the motor and will re-start automatically after a period of rest. If overload remains, the relay cycles to keep motor temperature within safe limits.

This design offered important cost savings, but to meet performance standards, the springs had to retain original calibration precisely over long periods of time. Since design simplification required that the spring blades carry the full starting and running current of the motor, a good conducting spring material was essential. Beryllium copper was tried and successfully met all requirements. It stood up under heating induced by over-load currents, did not drift after initial factory adjustment, and had ample endurance strength. The redesigned unit went into production in 1938 and is still being made in essentially the same form.

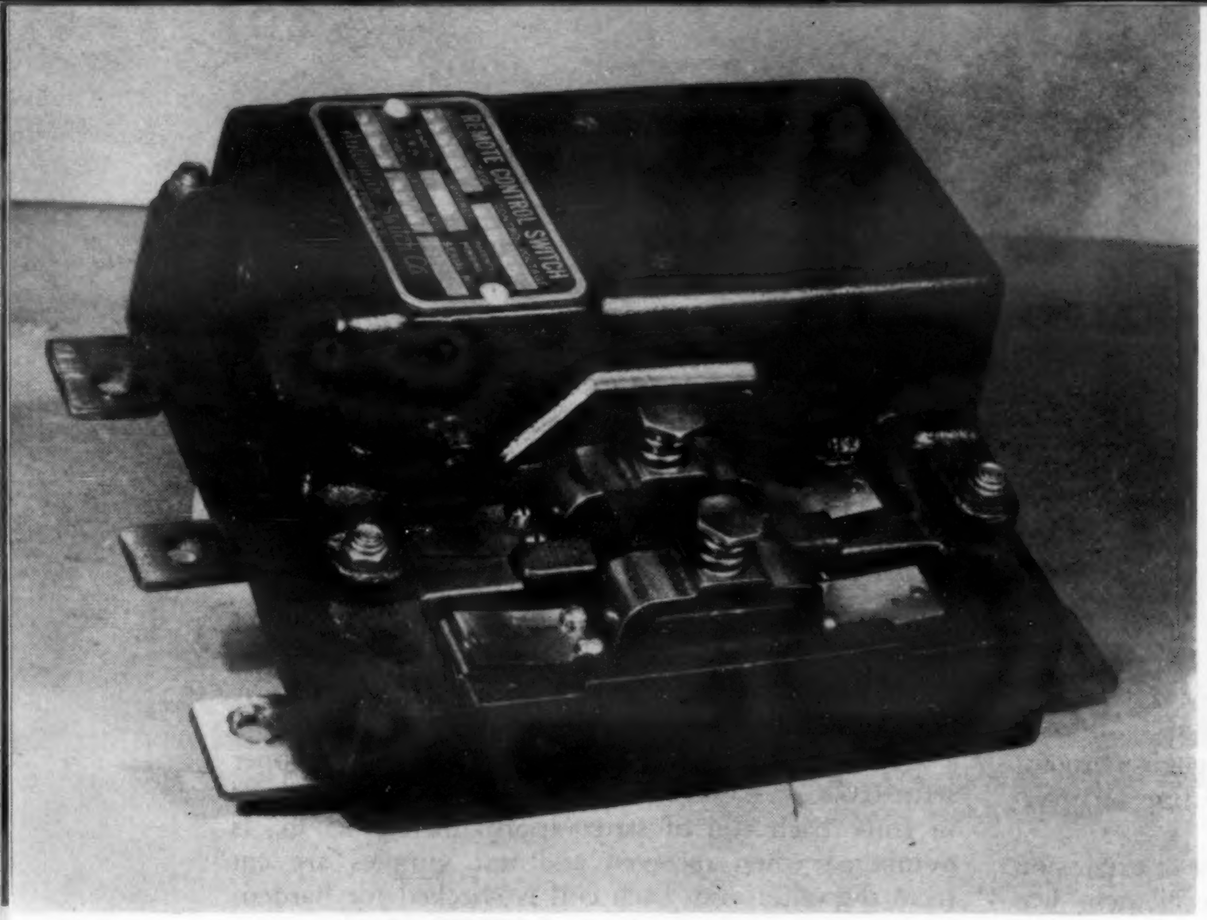
The spring blade is made from beryllium copper strip 0.006 ±0.0005 thick, ½ in. wide, 4 nos. hard in coils. Each coil of strip, approximately 15 lb., is numbered when received and test samples are cut from the outer end. Each coil is checked for hardening response to a minimum of 15N79. Hardness test specimens are heated along with regular production in sheet steel trays in a circulating air oven held at 600 F for 2 hr. In addition to the hardness test, 10% of the samples are also checked for tensile and elongation both before and after hardening.

In a recent shipment of strip, typical of usual material, the test results were:

	As Received	*Hardened*
Tensile Strength, Psi	111,000 to 121,000	194,000 to 213,000
Hardness	15 T 90-92.5	15 N 79-81
Elongation	1%	1%



Each of the two identical beryllium copper spring blades in the Delco control is punched in a progressive die; in the next operation contact is attached and center tongue bent, and then the assembly heat-treated in a circulating air oven.



Heavy duty, remote control lighting switch made by Automatic Switch uses beryllium copper for all springs to reduce manufacturing cost and at the same time improve operating performance.

As a check for excessive distortion occasionally encountered, about 6 ft. of strip from each coil of acceptable hardening response is made into finished parts, and checked for warpage. If distortion is excessive, a recheck is made and if found again the coil is not used.

Spring blades are made on a progressive die with stock fed through a roll straightener. Special attention is given to avoiding any burrs along the sides of the center tongue since life tests indicate that fatigue failure may result. These burrs, which form after the tool starts to wear, usually determine the length of the press run before the tool must be removed for sharpening. Usual production runs are 50,000 to 100,000. Cadmium plated strip is being tried to increase the production runs between sharpening of the die.

In the next operation, contacts are staked on each blade and the tongue bent to an angle of 20 deg. in a single set-up. Staking is done before heat-treating so riveting strain can be relieved in hardening. Parts are placed in a single layer in shallow steel trays and heated in a circulating air oven held at 600 F, with a maximum permissible variation of 5 deg. as indicated by a recording temperature controller. Heating time is 2 hr. after the recorder indicates the furnace has reached 600 F. No check is made on hardness after heat-treatment.

Springs are attached to arms by staking, and then assembled in the control. The link between the two springs is adjusted, stationary contacts are bent for proper relation between opening of the two snap switches, and the operating current setting made by adjusting the tension of the hot wire.

Samples from each week's production are checked for durability, and must run 2 million cycles or more. Occasional failures occur during this performance test, usually well beyond 2 million cycles and due to wear in the notch in the end of the center arm.

One of the earliest applications for beryllium copper coil springs was a mandrel-coiled compression spring made by Instrument Specialties for a magnetically operated remote control switch built by Automatic Switch Co. This switch uses a unique solenoid type movement for operating the contacts. Operating motion is obtained from a magnetic iron core in the solenoid acting through a long compression spring.

The spring material had to be non-magnetic since it operated within the solenoid field, and also corrosion resistant to outdoor weather. Installations of this type require a switch capable of operating over a wide voltage range to accommodate long control wire runs and line voltage variations. The core spring, therefore, had to be held to close limits on load-deflection rate and free length. Low drift or freedom from change of tension in service was important for the same reason.

Stainless steel springs used at first met the requirements for corrosion resistance and non-magnetic properties, but variations in free length and deflection rate made it necessary to select springs for each switch. To compensate for drift in service, the springs had to be selected a little on the strong side, which used up quite a bit of the tolerance range.

An investigation of drift in beryllium copper had just disclosed it had unusually stable properties, and in 1938 some beryllium copper springs were made on a regular coiling machine. They proved to be relatively free from drift, but variations in free length and load test were greater than for stainless as the result of distortion that took place during hardening.

The problem of uniformity was taken to Instrument Specialties who had made the drift study, and was solved by the development of a special mandrel coiling machine (patented) which coiled a continuous string of springs on a steel mandrel. When heat-treated on the mandrel the springs set to the shape in which they were coiled; they were then removed, cut apart, and the ends ground square.

By using a precision lead screw for the coiling guide it was possible to lay the wire on the mandrel with much greater accuracy than obtained in usual

coiling machines in which the final dimensions of the spring are a function of spring back or temper in the wire. To make the beryllium copper springs conform or set accurately to their coiled shape, a heat-treating temperature of 700 F was used with the time at a temperature selected to give the springs the lowest rate of drift under load.

Because of the relatively short heat-treating time, usually 12 to 15 min. and the necessity for accurate control of heating time, the higher hardening temperature required a salt bath. Quenching into cold water established the end of the heating time. To remove all traces of the salt, heat-treated mandrels were washed in a cleaner, rinsed and dried.

With the development of mandrel coiling, not only was the problem of hardening distortion solved, but it was also possible to control free length, coil diameter and load-deflection rate to much closer tolerances. With its low drift properties, beryllium copper then solved the problem.

Performance specifications and dimensional tolerances originally set up and maintained through many years of production on this spring are:

Free length	3.812	±0.050 in.
Outside diameter ...	0.415	±0.005 in.
Wire size	0.0453	—
Number of coils ...	27	—
Test load	6 lb. 3 oz.	—
Length under load ..	1.812	±0.050 in.
Drift, 1 hr. under test load	0.001 in. max.	

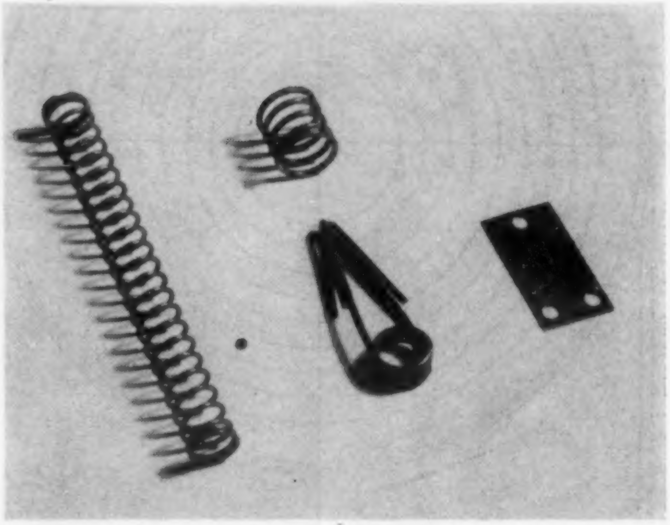
Springs are checked for load test using an Electronic Micrometer spring tester. Production is spot checked for drift on the same instrument.

Material used for these springs is purchased under a specification calling for a minimum tensile strength of 200,000 psi. after hardening. Wire is ordered 3 nos. hard in coils, with a silver coating which reduces wear on coiling tools.

Beryllium copper for this core spring was so successful in cutting assembly cost and improving performance of the switch that its use was considered for each of the other springs in this switch. After some development and minor redesign, beryllium copper was adopted in 1938 for all of the springs. These included, in addition to a long core spring, a fixture heat-treated flat spring for accurate positioning of the arcing contacts, short compression springs to provide and hold the desired contact pressure without set under elevated operating temperature, and a torsion spring used in the operating linkage giving more operating power than obtainable with a bronze spring.

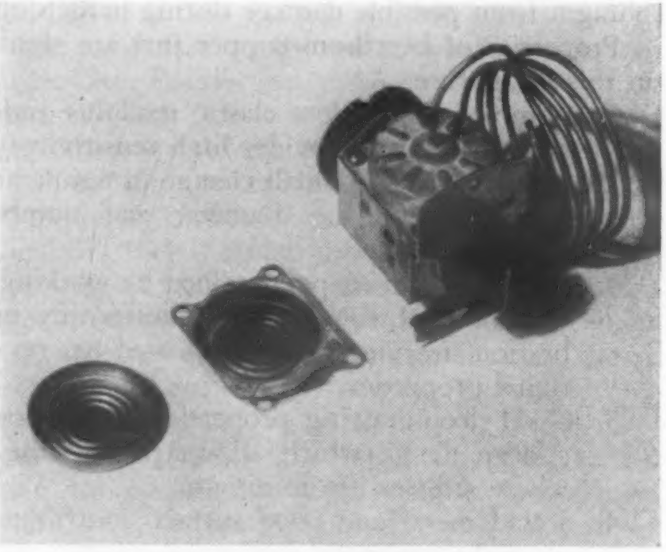
One of the earliest large scale applications for this lighting switch, after changing over to beryllium copper, was for the central fountain at the World's Fair in New York. Today, it is extensively used for manual or remote control of lighting loads up to 200 amp.

Beryllium copper has made one of its most significant contributions as a diaphragm material. One of the pioneer production applications, still going strong, was in the Cutler-Hammer refrigerator temperature control. Beryllium copper made the development of this device possible and set much higher standards of performance than previously obtainable at reasonable cost. Re-evaluation of the design today shows that beryllium copper still remains the lowest cost answer.

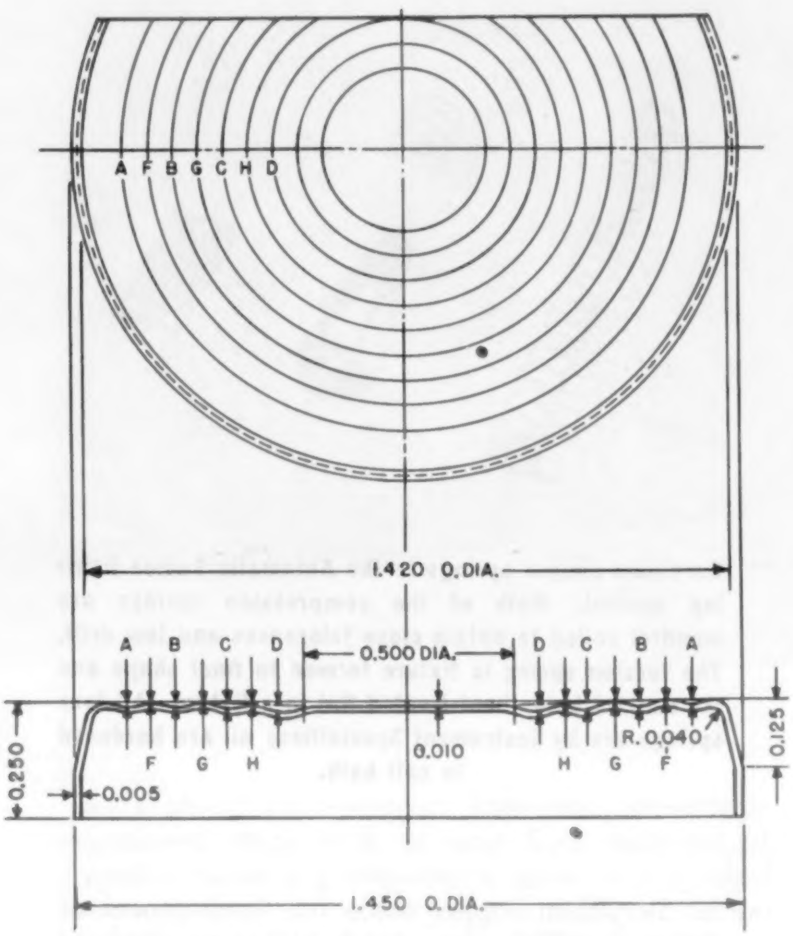


Beryllium copper springs in the Automatic Switch lighting control. Both of the compression springs are mandrel coiled to obtain close tolerances and low drift. The torsion spring is fixture formed to final shape and the contact blade heat-treated flat in a fixture. All four springs are by Instrument Specialties; all are hardened in salt bath.

The problem faced by Cutler-Hammer engineers back in 1937 was to design a control having (1) greater sensitivity, (2) smaller size, and (3) lower cost. Beryllium copper was just then becoming available in thinner gages, and its properties appeared promising. The first approach was a two-section wafer assembled by silver soldering. This design was soon followed by the final answer in the form of a single



Cutler-Hammer's refrigerator thermostat was one of the earliest production-scale uses of beryllium copper for diaphragms. The drawn cup is welded inside the brass shell, which serves as a heat-treating fixture during hardening.



Deep draw in the Cutler-Hammer diaphragm requires careful control of raw material, but has the advantage of placing the welded joint where operating stresses are minimum.

single section diaphragm assembled inside a brass shell or cup and sealed by welding.

One of the unusual aspects of this design is that the brass cup in effect becomes a heat treating fixture. By welding the diaphragm to the cup *before* heat treatment, distortion of the mounting flange—a common cause of non-uniform deflection rate—is effectively prevented, and the brass cup protects the diaphragm from possible damage during hardening.

Properties of beryllium copper that are significant in this design are:

1. Combination of low elastic modulus and high strength which provides high sensitivity (large displacement for small change in temperature), thus reducing the diameter and number of sections required.
2. Uniformity in shape, obtained by working with soft material, contributes to uniformity in calibration. (Annealed material used has no directional properties.)
3. Good deep-drawing properties permit forming a deep flange which allows placing the weld where stresses are minimum.
4. Sound metal and good surface contribute to a gas-tight structure.
5. Corrosion resistance to moisture and food acids.
6. Freedom from drift or creep (obtained by higher temperature heat treatment) gives the control performance comparable to that of an instrument.

Material for the diaphragm is purchased in the form of strip 2 in. wide, and 0.005 in. thick with a tolerance of ±0.00025 in. on thickness. Strip is supplied in coils, annealed with a maximum grain size of 0.035 mm. and a hardness specification of 15 T 78 to 85, as measured on a diamond anvil with a steel ball.

Each coil received is checked for hardness on samples taken from both inside and outside the coil. Specimens are then heat-treated along with regular production at a temperature of 635 F for 2½ hr., and again checked for hardness to a minimum of 15 T 94. Spot checks are also made on tensile strength before and after hardening on those coils showing low hardness as received. Coils with high hardness as received are checked by running a few feet of strip through the die. If the material draws properly the coil is used.

Tooling used is a compound die which produces the diaphragm complete in one operation. Several duplicate tools are provided so that production can be maintained when tools must be removed for sharpening.

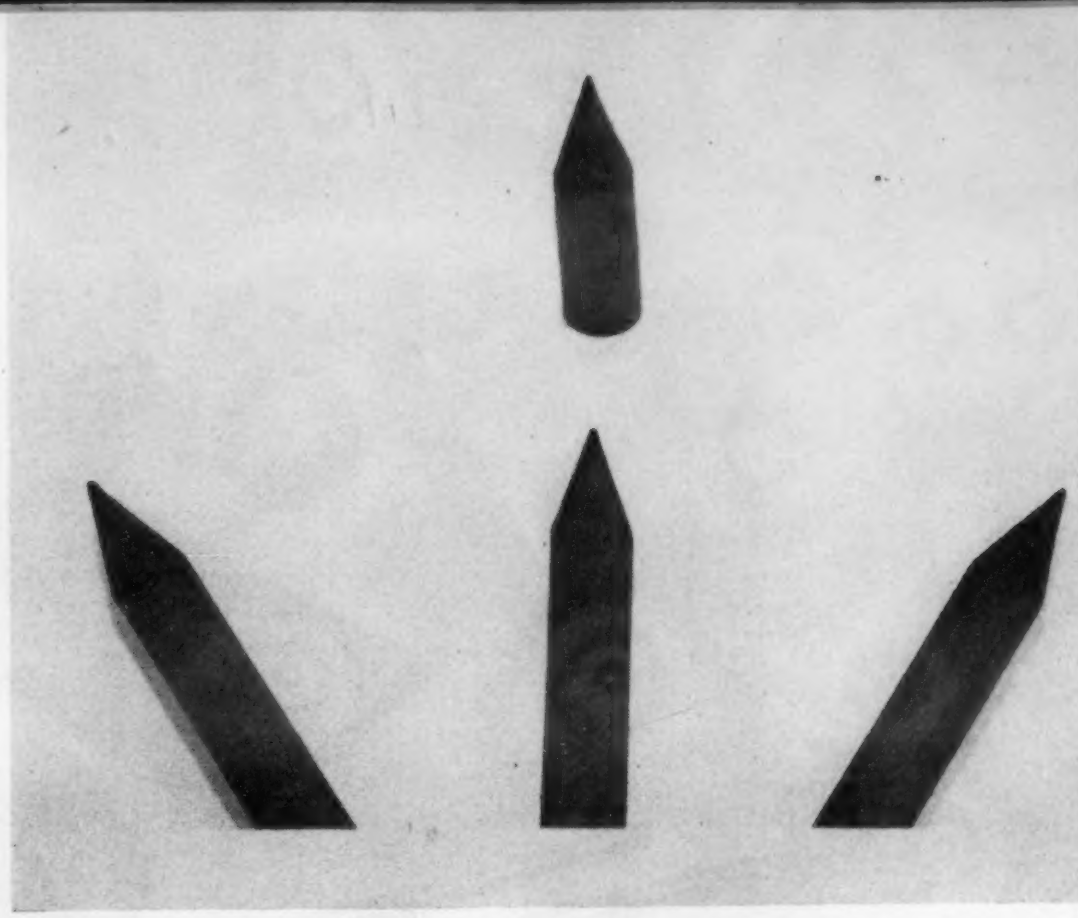
Diaphragms as they come from the tool are welded to the brass cups or holders and heat-treated in wire mesh baskets holding about 200 pieces, in a circulating air electric furnace. A recording temperature controller holds temperature well within 5 deg. for the 2½-hr. heat treatment. Work is loaded with the furnace at temperature and the measured time starts with loading. Care is exercised to maintain uniform loads.

After hardening, the capillary tube is attached to the holder, the gas charge added, and the pressure system sealed. Units are then aged at about 165 F to test for leaks, and then assembled into controls. The complete control is given another aging period at 190 F, which is a far more severe test than it will ever receive in use, and serves as a thorough check on any tendency to drift or set. After this test the final calibrating adjustments are made and the control is ready to ship.

Samples from production are taken regularly and life-tested for 500,000 cycles at a load corresponding to the normal operating range. Changes found in temperature settings measured after the life test give an accurate measure of the stability. Endurance failures are rare, but when they do occur the diaphragm fractures where the flange joins the corrugated section, usually as the result of strip lacking in ductility.

These are but four typical examples. Many other equally interesting case histories could be cited. For example: speed governor for adding machines, calibrated spring for aircraft tachometer, diaphragms in two more refrigerator thermostats, a leaf spring in room thermostat, blades in several other snap switches, diaphragm for pressure gage, contact springs in motor control, core guides in power solenoids, bourdon tubes for steam gage. But in every case the story is much the same. Where an application has stood the test of time, it is because the designer had the opportunity and the vision to design to take full advantage of what beryllium copper had to offer.

NEW MATERIALS PREVIEW



Pins such as these made of K 138 as supports in porcelain enamel firing furnaces have shown a useful service life of 6 weeks.

Carbides for High Temperature Applications

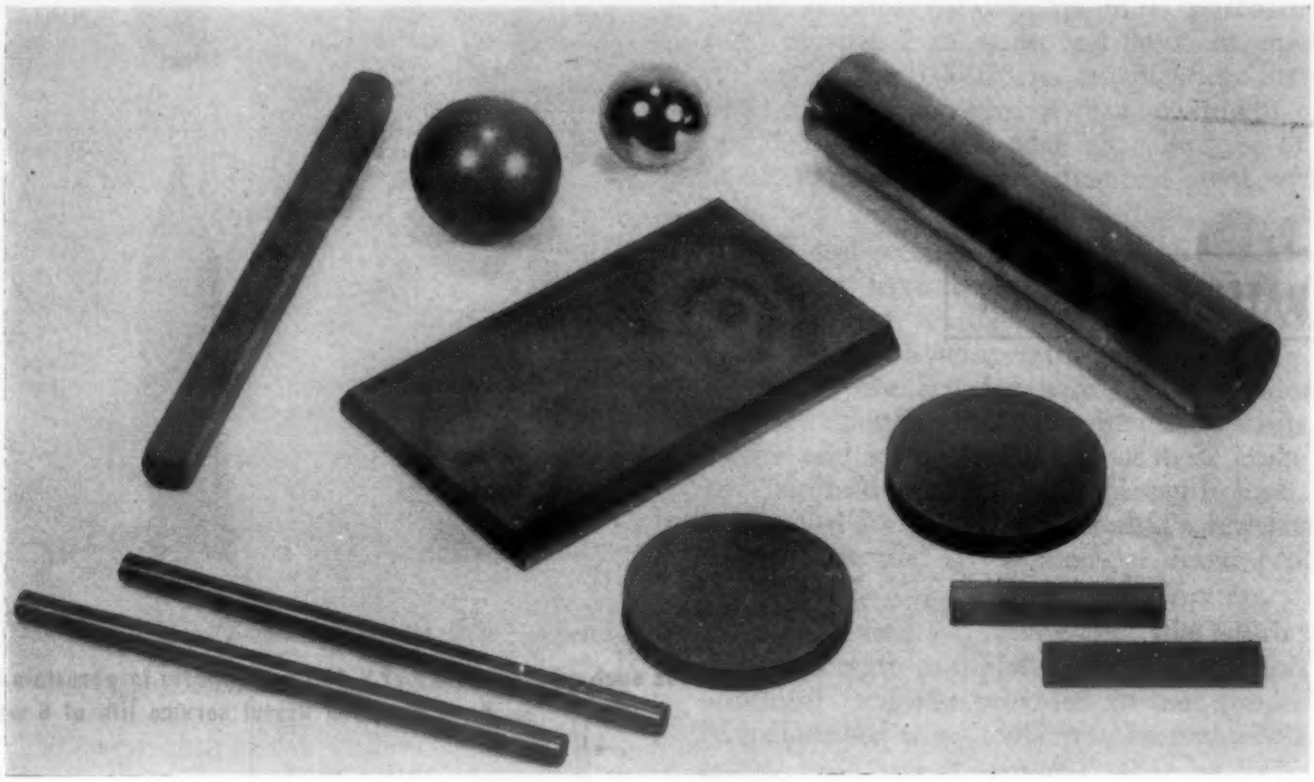
This new material in the "ceramal" group has excellent properties at elevated temperatures and looks promising for such uses as gas turbine buckets and furnace parts.

A NEW CARBIDE designed specifically to stand up under temperatures which rapidly destroy conventional carbide compositions has been developed by Kennametal Inc., Latrobe, Pa. The material known as Kennametal Grade K 138 is characterized by its light weight (⅔ the density of ferrous alloys), high thermal conductivity, high thermal shock resistance, and high strength and corrosion resistance at elevated temperatures.

As yet, K 138 is too new to have been widely applied. However, it is being used as pins for supporting work going through porcelain enamel firing furnaces with excellent results. Actual service has shown a useful life of at least six weeks as compared to 10 hr. for cast nickel-chromium alloy pins. The NACA and other interested groups have been studying the use of K 138 for gas turbine buckets. Tests have not progressed to the point where results can be announced. Further suggested applications are for furnace parts, roll guides and other high temperature structures.

K 138 falls into a new category of materials for which the term "ceramals" has been coined. Ceramals contain both metals and compounds. Into this category are placed oxides admixed with a minor percentage of metal and fused following ceramic practice; or, hot pressed carbides admixed with metals and shaped and sintered by so-called powder metallurgy methods.

Methods used for making K 138 shapes are similar to those for making cemented carbide tool shapes, although some special processes were developed. K 138 contains no tungsten carbide, a major ingredient of all tool compositions. The cobalt metal used in K 138 is the same as that used in tool compositions and titanium carbide; the other principal ingredient of K 138 is also used in carbide cutting compositions. This is the first commercial composi-



Shown here are some of the shapes in which K 138 is produced.

tion with titanium carbide as the only carbide constituent.

Parts and shapes made of K 138 must be made reasonably close to final size, since the pressed and sintered product cannot be machined. Grinding can be used to attain final finishes. Some machining can be done when the material is in the "green" state before sintering, if complicated shapes are involved. The material cannot be brazed satisfactorily, so in most instances it must be fastened mechanically.

The strength at room temperature of K 138 is unaffected after heating at 2100 F for 48 hr. The heat shock properties are good, as is indicated by the fact that no change was observed in pieces which were heated repeatedly to 1800 F in a muffle furnace and quenched in water. Heating to the same temperature (1800 F) and air cooling had no effect other than the initial discoloration of the surface.

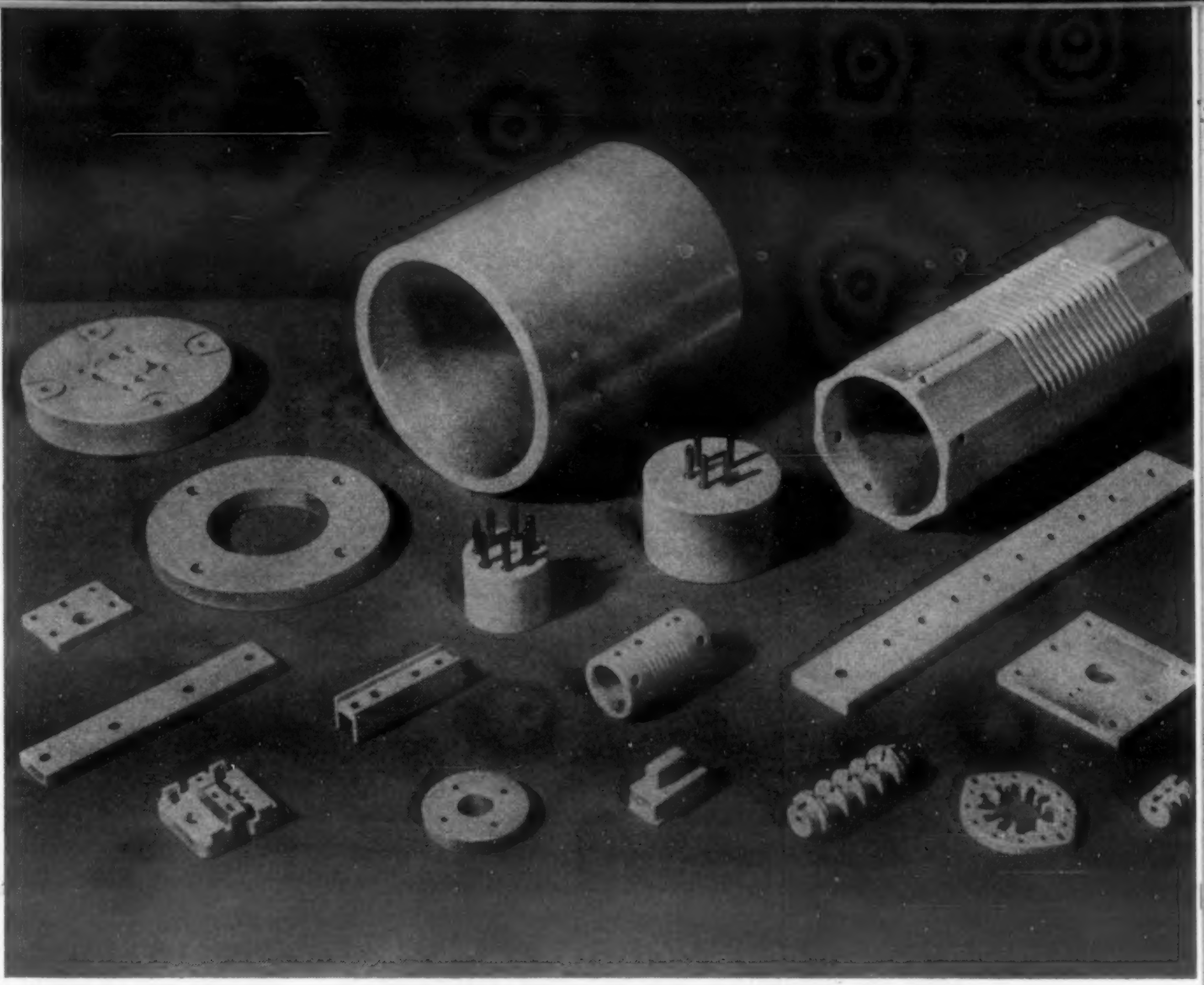
The accompanying table lists properties of K 138. Most of the characteristics of this material are superior to type 302 stainless steel and many of the cast and forged "super alloys." The latter group includes precision casting alloys and others with high cobalt or molybdenum, chromium, nickel, etc.

This exhaust valve seat for a Diesel engine is made with K 138.

Properties of K 138

Transverse Rupture Strength (Room Temperature)	175,000 to 210,000 psi.
Transverse Rupture Strength (1800 F)	100,000 psi.
Tensile Strength at 1800 to 2000 F	*15,000 to 21,000 psi.
Young's Modulus of Elasticity	55,000,000 psi.
Hardness, Rockwell A Scale	91.0 to 92.0
Specific Gravity	5.5
Thermal Expansion	5.0×10^{-6} per deg. F (300 to 1200 F)
Thermal Conductivity	0.085 cal./sec./deg. C/cm.
Electrical Conductivity	5.0% of copper standard
Resistance to Combustion Gases up to 2100 F	No apparent attack in 48 hr.

* *Indications are that this figure may be higher.*



Some new types of heating equipment make use of refractory ceramic burners such as these.

Properties and Uses of Technical Ceramics

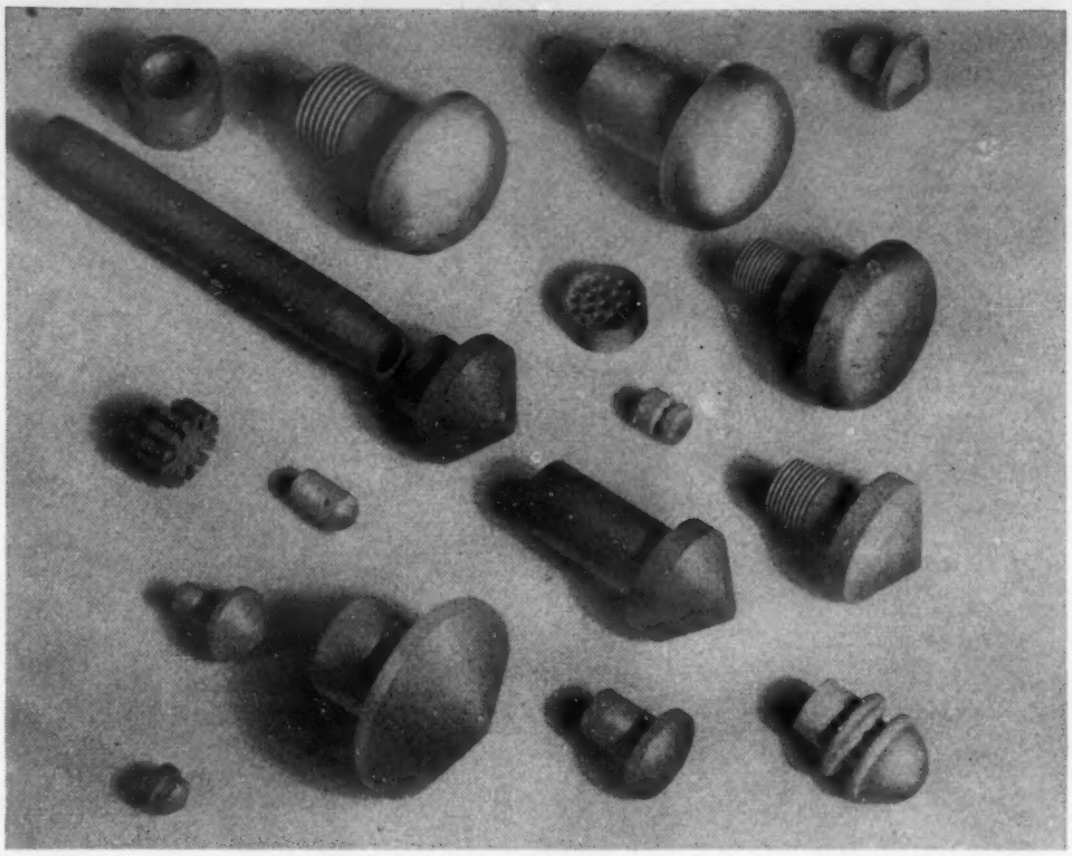
by **HANS THURNAUER,** *Director of Research, American Lava Corp.*

The special characteristics of technical ceramics make them useful for a number of important industrial products, including electronic insulators, refractory burners and fixtures for induction heating.

A CERAMIC PRODUCT IS MADE of earthy or inorganic materials and heated to a high temperature during its manufacture. This definition comprises the products of the ceramic industry, of which only some are well known to the layman, such as brick and tiles, sewer pipes and sanitary ware, dinner ware and products of art. It also includes the lesser known technical ceramic products, indispensable for the solution of many technical problems. Iron and steel manufacture is dependent on ceramic refractories for furnace linings, the chemical industry relies on acid resisting stone ware, porcelain, or glass; modern tool making cannot exist without ceramic grinding wheels and other abrasive products made by ceramic methods.

This discussion will be limited to some of the properties and applications of technical ceramic products which customarily fall under the term of "Ceramic Whitewares." It includes the diversified products of technical porcelain manufacture, both vitrified and porous types.

The technical study of ceramic materials on a scientific basis began only 40 odd years ago, but the art of ceramics can be traced back to ancient times. Improvements in testing methods contributed to the development of better ceramic bodies for new applications. The field of technical ceramics vastly expanded during the last 20 years, based on the utilization of new sources of raw materials, both natural and synthetic, and by adopting mass production methods which led to accurately formed products of reliable quality. Today it is possible to vary the properties of ceramics over a wide range by proper selection of raw materials, methods of preparation and forming, firing temperatures and firing schedules.



High frequency equipment uses a large portion of ceramic output for such parts as these low loss insulators.

Data on mechanical and electrical properties of technical ceramics have been published in technical publications and in manufacturers' literature; most of the data refer to specific materials. It is the purpose of this article to present a general survey of the more important properties and give examples of technical applications of products having advantageous properties.

Apparent Density and Moisture Absorption

Ceramic materials may be porous or vitrified (non-absorbent) and both types have their uses, depending upon the application. The porosity is usually measured by the amount of water which is absorbed and expressed as percentage by weight of water absorbed, or as that portion of the total volume of the mass which is taken up by pores.

Highly porous ceramics, with a water absorption of from 20 to 40% by weight serve as filters in purifying systems, catalyst carriers used in chemical applications, or as radiants for gas heating devices. Materials of medium porosity, varying from 2 to 15%, are preferred for electrical insulators used at elevated temperatures, such as ceramic cores for electrical heaters or resistors. For high voltage insulation, only vitrified materials can be used. Vitrification of a ceramic material is determined by immersing a fractured ceramic specimen in a solution of fuchsine dye and alcohol and subjecting it to a pressure of 4000 psi. For a vitrified body suitable for high voltage or high frequency applications, no dye penetration into the ceramic body is permissible. Bodies having no dye penetration, however, are not necessarily free from closed pores. As a matter of fact, most vitrified ceramic materials have a closed pore volume in the order of 2 to 6%, the amount depending on the method of manufacture and type of body. We, therefore, speak of an apparent density of a ceramic material which is the composite value of the true density of the material and its voids or pores. An anology can be found in cast or sintered metals which, also, have an apparent density less than the true density.

The apparent density of most ceramic materials is between 2 to 4 g. per $cm.^3$ They are, therefore, approximately twice as heavy as organic plastics, but only ½ to ⅓ as heavy as steel. Steatite ceramics with an apparent density of 2.5 to 2.8 have the same unit weight as aluminum.

Heat Characteristics

One of the outstanding properties of a ceramic material is its resistance to heat. Being composed of inorganic oxides, neither burning nor charring occurs at any temperature. The refractory value of a ceramic material is evaluated from its softening temperature. It is the temperature at which deformation takes place without application of load. If loads are applied, deformation will take place at lower values. In most cases, ceramics are used well below their softening temperatures and the danger of deformation under continuous load can be disregarded. Cold flow, a serious limitation of many organic plastics, is nonexistent for ceramics. Safe operating temperatures for ceramic materials are usually 200 to 300 C (392 to 572 F) below the softening temperature for porous bodies, predominantly of crystalline structure and 400 to 500 C (752 to 932 F) below the softening temperature for vitrified materials which contain an appreciable amount of glassy binder.

If ceramic materials are used at high temperatures, consideration must be given to the effect of other materials with which they may come in contact. Metals or metallic oxides may react with the ceramic, forming eutectic mixtures which may cause fusion at lower temperatures than the softening temperature of the ceramic indicates. A good example is the reaction of lead or lead oxide (from tetraethyl lead in high octane gasoline) with the ceramic spark plug core. Special nonreactive ceramic compositions

have to be chosen to avoid the deterioration of the insulator from this cause. Ceramics high in alkali content may react at comparatively low temperatures with chromium oxide, originating from chromium-nickel resistance wires, and cause failure of electric heating elements.

The ability to withstand sudden temperature changes without cracking is an important requirement for many ceramic applications but is a property hard to obtain. Heavy or irregular cross sections may crack under thermal stresses, whereas thin and uniform crossection of the same composition might stand up very well under the same conditions. O. Schott and A. Winkelmann established an empirical formula to grade the thermal shock resistance of glasses, which, in a limited way, is also applicable for other ceramic materials.

$$W = \frac{T}{E.n}\sqrt{\frac{K}{p.c}}$$

W = Thermal shock resistance
T = Tensile strength
E = Modulus of elasticity
n = Coefficient of thermal expansion
K = Thermal conductivity
p = Specific gravity
c = Specific heat.

The formula states that a material of good thermal shock resistance has to be of low modulus of elasticity, low coefficient of thermal expansion, high thermal conductivity, low heat capacity. Unfortunately, only thermal expansion and thermal conductivity can be varied to an appreciable extent. Vitrified products in

Table 1—Melting Points of Refractory Oxides Used in Ceramics

	Deg. Centigrade
1. Thorium Oxide	3050
2. Magnesium Oxide	2800
3. Zirconium Oxide	2700
4. Calcium Oxide	2570
5. Beryllium Oxide	2570
6. Strontium Oxide	2430
7. Aluminum Oxide	2050
8. Chromium Oxide	1990
9. Silicon Dioxide	1710
10. Titanium Dioxide	1640

Table 2—Comparison of Moh's Hardness and Knoop Hardness Numbers

Mohs' Scale	Specimen	Knoop Indenter Number
1	Talcum	—
2	Gypsum	32
3	Calcite	135
4	Fluoride	163
5	Apatite	395
6	Orthoclase	560
7	Quartz	750
8	Topaz	1250
9	Corundum	1635
10	Diamond	8000-8500

Table 3—Comparison of Some Typical Structural Materials

	Vitrified Ceramics	Porous Ceramics	Glass	Organic Plastics	Steel	Aluminum
Apparent Density, g./cm.^{3}	2-4	1.6-2.8	2-3	1-2	7.8	2.7
Safe Operating Temp. Deg. C	800-1500	900-1600	400-500	60-200	(Heat resisting) 650-850	200
Thermal Conductivity g. cal. x cm.						
Cm.^{2} x sec. x Deg. C	0.002-0.05	0.003-0.005	0.002-0.004	0.0002	0.1	0.5
Linear Expansion per Deg. C	3.5-10.5	2.5-11.5	2.5-11.0	20-120	7.5-19	23.9
Modulus of Elasticity, 10^6 Psi.	7-52	2-10	9-11	0.1-3.5	30	10
Tensile Strength, Psi.	3000-30,000	700-3500	6000-10,000	4000-8000	80,000-300,000	30,000-60,000
Compressive Strength, Psi.	25,000-250,000	15,000-60,000	50,000-170,000	7000-30,000	—	—
Flexural Strength, Psi.	9000-45,000	1500-9000	7000-18,000	7000-15,000	—	—
Impact Strength, Ft.-Lb.	0.2-0.7	0.1-0.3	0.1-0.3	0.3-3.5	.+50	—
Dielectric Strength, V./Mil.	50-400	40-100	400-600	400-600	—	—
Resistivity Room temp., Ohms/Cm.^{3}	10^8-10^{15}	10^{12}-10^{15}	10^{12}-10^{15}	10^{12}-10^{19}	10x10^{-6}	2.8x10^{-6}
Te-Value Deg. C	300-1100	300-1100	200-300	—	—	—
Dielectric Constant	5-5000	4-7	4.0-8	2.5-4.5	—	—
Power Factor (1MC)	0.05-0.0002	0.01-0.0002	0.01-0.0005	0.01-0.0001	—	—

Table 4—Typical Applications and Physical Properties of Some

	VITRIFIED PRODUCTS				
	Chemical and High Voltage Porcelain	Alumina Porcelain	Zircon Porcelain	Steatite	Titania, Titanate Ceramics
Typical Applications	Chemical laboratory ware power line insulation	Sparkplug cores, thermocouple insulation, protection tubes	Sparkplug cores, high voltage-high temp. insulation	High frequency insulation, electrical appliance insulation	Ceramic capacitors lightning arrester insulation
Specific Gravity (gm/cc)	2.3-2.5	3.1-3.9	3.0-3.8	2.5-2.7	3.5-4.0
Water Absorption (%)	0.0	0.0	0.0	0.0	0.0
Mohs' Hardness	7.0	8.5-9.0	7.5-8.5	7.0-7.5	7.0-8.0
Coefficient of Linear Thermal Expansion per deg. C (20-700)	$5.0\text{-}6.8 \times 10^{-6}$	$5.5\text{-}8.1 \times 10^{-6}$	$3.5\text{-}5.5 \times 10^{-6}$	$8.6\text{-}10.5 \times 10^{-6}$	$7.0\text{-}10.0 \times 10^{-6}$
Safe Operating Temp. (deg. C)	1000	1350-1500	1000-1200	1000-1100	800-1000
Thermal Conductivity (cal./cm.^{2}/cm./sec./deg. C)	0.002-0.005	0.007-0.05	0.010-0.015	0.005-0.006	0.008-0.01
Tensile Strength (Psi.)	3000-8000	8000-30,000	10,000-15,000	8000-10,000	4000-10,000
Compressive Strength (Psi.)	25,000-50,000	80,000-250,000	80,000-150,000	65,000-130,000	40,000-120,000
Flexural Strength (Psi.)	9000-15,000	20,000-45,000	20,000-35,000	16,000-24,000	10,000-22,000
Impact Strength, Ft.-Lb.	0.2-0.3	0.5-0.7	0.4-0.5	0.3-0.4	0.3-0.5
Modulus of Elasticity (Psi.)	$7\text{-}14 \times 10^{6}$	$15\text{-}52 \times 10^{6}$	$20\text{-}30 \times 10^{6}$	$13\text{-}15 \times 10^{6}$	$10\text{-}15 \times 10^{6}$
Thermal Shock Resistance	Moderately good	Excellent	Good	Moderate	Poor
Dielectric Strength (V./Mil) (¼-in. thick Specimen)	250-400	400	250-350	200-350	50-300
Resistivity (ohm/cm.^{3}) at Room Temp.	$10^{12}\text{-}10^{14}$	$10^{14}\text{-}10^{15}$	$10^{13}\text{-}10^{15}$	$10^{13}\text{-}10^{15}$	$10^{8}\text{-}10^{15}$
Te-Value, deg. C	300-500	700	700	450-1000	200-400
Power Factor at 1MC	0.006-0.010	0.001-0.002	0.0002-0.0020	0.0002-0.0035	0.0002-0.050
Dielectric Constant	6.0-7.0	7.3-11.0	8.0-10.5	5.5-7.5	15-5000
Loss Factor at 1MC	0.036-0.070	0.007-0.022	0.0016-0.0210	0.001-0.026	—

Note: The above figures represent comparative values only and vary within rather wide limits, depending on method of manufacture, size and shape, etc.

particular have a very high modulus of elasticity and usually show poor heat shock characteristics. Thermal expansion of ceramic materials can be varied between 1 and 12 x 10^{-6} per deg. C. The low expansion bodies, such as cordierite materials, are among the best ceramics resistant to heat shock and can be heated to red heat and dropped immediately in ice water without damage.

Controlling and lowering thermal expansion of ceramic materials is used not only for improvement of thermal shock qualities, it is also important for matching thermal expansion of other materials used in conjunction with ceramics. Metal-ceramic seals, important in the development of high frequency vacuum tubes, have to be built from materials with matched thermal expansions to avoid strains, distortion, or cracking. Wire wound enameled resistors serve as an example of matching three materials for thermal expansion. The ceramic core, the resistance wire, and the enamel cover have to be carefully matched to withstand repeated heating and cooling in service.

In designing high frequency electronic equipment or components, advantage can be taken of the fact that the thermal coefficient of expansion of a ceramic material is reproducible within close limits. It is possible to calculate the dimensional and resultant electrical changes caused by temperature and correctly compensate for these predictable variables.

Ceramic materials are not only poor conductors of electricity but also poor conductors of heat. This can be expected since both properties are dependent on electronic vibrations within the material. The thermal conductivity of a ceramic material can, therefore, be increased only at the expense of the dielectric properties.

Hardness and Abrasion Resistance

The hardness of brittle ceramic materials cannot be

POROUS AND REFRACTORY PRODUCTS			
Low Voltage Porcelain	Cordierite Refractories	Alumina, Aluminum Silicate Refractories	Massive Fired Talc, Pyrophyllite
Switch bases low voltage wire holders, light receptacles	Resistor supports, burner tips, heat insulation, arc chambers	Vacuum spacers, high temp. insulation	High frequency insulation, vacuum tube spacers, ceramic models
2.2-2.4	1.6-2.1	2.2-2.4	2.3-2.8
0.5-2.0	5.0-15.0	10.0-20.0	1.0-3.0
7.0	7.0	7.0-8.0	6.0
5.0-6.5x10^{-6}	2.5-3. 0x10^{-6}	5.0-7.0x10^{-6}	3.6 pyrophyllite, 11.5 talc
900	1250	1300-1600	1200
0.004-0.005	0.003-0.004	0.004-0.005	0.003-0.005
1500-2500	1000-3500	700-3000	2500
25,000-50,000	20,000-45,000	15,000-60,000	20,000-30,000
3500-6000	1500-7000	1500-6000	7000-9000
0.2-0.3	0.2-0.25	0.17-0.25	0.2-0.3
7-10x10^{6}	2-5x10^{6}	2-5x10^{6}	4-5x10^{6}
Moderate	Excellent	Excellent	Good
40-100	40-100	40-100	80-100
10^{12}-10^{14}	10^{12}-10^{14}	10^{12}-10^{14}	10^{12}-10^{15}
300-400	400-700	400-700	600-900
0.010-0.020	0.004-0.010	0.0002-0.010	0.0008-0.010
6.0-7.0	4.5-5.5	4.5-6.5	5.0-6.0
0.060-0.140	0.018-0.055	0.0009-0.065	0.004-0.060

measured by the same methods customarily used for ductile materials, such as metals or organic plastics. The relative hardness of ceramic materials can be expressed by using the so-called Mohs' Scale, which was set up by the mineralogist Mohs more than 100 years ago. The specimen is rubbed against a set of sample minerals of varying hardness and identified with a number, corresponding to that of the mineral which does not scratch nor abrade. An improved scientific method has recently been developed by Knoop, Peters and Emerson of the U. S. Bureau of Standards. A defined indentation is obtained on both ductile and brittle materials and indentation hardness values are obtained. The "Knoop hardness" of vitrified ceramics varies from 600 for hard porcelain to 2230 for boron carbide, the hardest man-made material. The resistance to abrasion of a brittle material is directly related to its hardness, and ceramic materials are, therefore, widely used where abrasion resistance or grinding qualities are the determining factors. The abrasives industry is based on the two ceramic raw materials: aluminum oxide and silicon carbide. Extrusion nozzles, textile thread guides are made of vitrified abrasion resistant ceramic materials which have a smooth surface and can be polished to a high degree.

Other Physical Properties

An elastic body returns to its original shape after removal of the distorting force. Ceramic materials are ideal elastic bodies because they break without any trace of plastic deformation. The displacement of the various particles of a body relative to one another, produced by external forces, is called a strain. Elastic bodies resist strains by setting up internal restoring forces called stresses. The ratio, within the elastic limits of a material, of stress to corresponding strain is called the modulus of elasticity (Young's modulus). For ceramic materials, the modulus of elasticity is in the same order or magnitude as for steel. Organic plastics, on the other hand, have a modulus of elasticity a tenth to a twentieth smaller than ceramics.

For ceramic materials, the elastic limit and the ultimate breaking point is practically identical. They do neither permanently stretch nor flow under load or strain, but return to their original shape after release of strain. Compared with metals which have high tenacity, ceramic materials are brittle. Their impact resistance is low and most mechanical failures can be attributed to impact blows. The proverbial bull in a china shop has, therefore, an easy task.

Mechanical strength values of ceramic materials are customarily expressed in load per unit area cross section at which failure occurs. It is important to realize, however, that the distribution of stresses set up by load are not uniformly distributed over the cross sectional area, but are concentrated on the outer surfaces. Mechanical strength values per unit area of ceramic materials decrease with increasing cross sections and in evaluating or comparing data of rigid materials, it is important to take into consideration the cross sectional area of the test specimen.

Vitrified ceramic materials show compressive strength values in the same order of magnitude as metals. Tensile and flexural strength values, on the other hand, are much lower. It, therefore, is desirable to load ceramic materials by compression rather than by tension. Most suspension high voltage insulators are designed for compression loads.

Chemical Resistance

Chemical resistance, *i.e.* the resistance against the attack of corroding chemicals, depends on the composition and physical structure of a material. Vitrified ceramic bodies are more resistant against chemicals than porous bodies. Most ceramic materials withstand the action of acids, with the exception of hydrofluoric acid, which decomposes silicates to gaseous silicon fluoride. The resistance of ceramics to strong alkalies or to super-heated steam is not always satisfactory, but it is possible to formulate body compositions which will give very good service under all conditions of chemical attack.

Chemical stone ware and porcelain are outstanding building materials in chemical engineering.

Electrical Properties

The use of ceramics as electrical insulators can be traced back to the inception of electrical technology itself and has kept pace with the advancement of electrical science. The importance of ceramic insulators in our economy can be judged by the fact that in 1943 the various applications for ceramic insulating materials consumed about $44,000,000 worth (or 40%) of the American White Ware industry's total output.

Dielectric Strength: The dielectric or breakdown strength of an insulating material is the voltage gradient at which electrical breakdown occurs. Since dielectric breakdown depends on a number of factors, such as thickness of test specimen, duration, rate of increase of the applied voltage, frequency, wave shape, electrostatic field distribution, etc., it is necessary to maintain uniform test conditions to obtain comparative values.

Only vitrified ceramic bodies can be considered satisfactory for high voltage applications. Porous materials have a dielectric strength equal to air, therefore, only 1/5 to 1/10 that of vitrified materials.

Volume Resistivity: Volume resistivity of vitrified ceramic insulating materials at room temperature is in the order of millions of megohms. It is equally high for porous materials in dry atmosphere, but drops rapidly with increasing humidity. Volume resistivity of ceramic insulating materials at elevated temperatures is an important property and a determining factor for the selection of insulating materials used in electrical heating appliances. The usefulness of a ceramic material as insulators at elevated temperatures is usually evaluated by its "Te-value," which is that temperature in deg. C, at which the volume resistance of the material is one megohm/cm.[3] Some ceramic materials have Te values well above 1000 C.

Surface Resistance: Since most ceramic materials have a relatively rough surface (unless glazed or polished), a continuous moisture film can easily collect on the surface. In most cases, surface resistance determinations actually measure the resistance of the moisture film rather than the surface as such.

Where low surface resistance is objectionable, it is advisable to treat the surface with moisture repellent organic substances. Ceramic radio insulators which are exposed to moisture and operate under all existing climatic conditions are surface treated with organic waxes or silicone compounds. For outdoor installations, glazing of exposed surfaces is recommended; a smoothly glazed surface not only sheds water but also facilitates cleaning.

Dielectric Constant: No other insulating materials have as wide a range of dielectric constant values as ceramic materials. They can be produced with a dielectric constant of 5 up to values of 4000. High dielectric constant value is technically important when the material is used as a dielectric of a condenser, in order to get maximum capacity per unit space. The capacity of a dielectric condenser is not only proportional to the dielectric constant of the dielectric but inversely proportional to the thickness of the dielectric. Since it is not practical to manufacture ceramic materials in layers as thin as obtainable in other dielectric materials, highest capacity values are still obtained by using a multiplicity of thin layers of mica or paper.

A most important characteristic of ceramic condenser dielectrics is the capacitance change with temperature. It is possible to produce ceramic materials with either positive or negative temperature coefficient of capacitance and by proper combination, ceramic materials can be formulated with capacitances practically independent of temperature. High frequency condensers using such ceramic materials as dielectrics can be counted among the most accurate and stable condensers available.

Power Factor and Dielectric Loss: It has been the aim of high frequency research to develop materials with low power factor. High frequency ceramics have been developed which meet all the requirements for insulation in the high frequency field. Low loss steatite ceramics with very low dielectric losses are extensively used wherever rigidity, high mechanical strength, and low dielectric losses have to be the determining factors. The production of low loss steatite insulators during World War II materially contributed to the high quality of our electronic equipment.

An interesting and novel application of low loss ceramic materials is for fixtures to be used in high frequency heating equipment. Low loss ceramics with good heat shock resistance can be exposed to the intense high frequency field, in which metals are brazed, sintered or melted, without being affected by the dielectric field. They can be accurately machined and retain their shape even at the high heat generated during the brazing operation.

Design Criteria

Ceramic manufacturing processes are rather complex, and it is beyond the scope of this article to describe the varied method of forming ceramics. The user of ceramic materials should become acquainted with these processes to better understand the possibilities and limitations of ceramic materials. Some very useful information along these lines has been published by various manufacturers of technical ceramics and by the National Electrical Manufacturers Association.

At the beginning of World War II, the American Standards Association undertook the task to establish American War Standards for technical ceramics, and these standards have proved so valuable that they have been adopted as standards, practically unchanged, by the National Electrical Manufacturers Association. There is no doubt that the practices of standardization will give further impetus for the economical production of technical ceramics and at the same time raise the quality level of the standardized product.

Adherence to established design practices and close cooperation between the designer and manufacturer of technical ceramics will be the best insurance for the successful solution of technical problems.

MATERIALS & METHODS MANUAL 32

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Organic Finishes for Metals

by H. R. Clauser, Associate Editor

To some, finishes of metal parts are just paint. Those who study them properly, classify organic coatings as engineering materials and make their selection on an engineering basis.

Presented here is a highly useful manual on organic finishes approached from the viewpoint of "what is needed in the finish," to help the engineer more intelligently select and apply finishes.

Contents

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The fine finish quality of lacquer is best obtained through airbrush application, as on this elevator door. (Photo: Courtesy Otis Elevator Co.)

Introduction

In recent years the organic coatings field has grown by leaps and bounds. Bewildering numbers of finishes have been developed; and there seems to be no end to this expansion, with new coatings being announced almost every day. Confronted with such a vast variety of coatings, it is little wonder that metal products manufacturers are sometimes confused and don't know exactly how to go about selecting the organic finish that will best fit the job.

It is to help them that this manual is written. It will describe the composition, characteristics and properties of organic finishes; it will explain the considerations involved in selecting a finish; it will discuss the properties and uses of the broad kinds of organic coatings—paints, enamels, lacquers, varnishes, and specialty finishes. It will be concerned mainly with the coatings used in production line finishing of metal parts, usually termed production or industrial finishes, and only slightly with structural steel and maintenance coatings.

One of the major tasks encountered in selecting finishes is trying to unscramble and understand nomenclature and definitions of basic words and terms. Experts in the organic finishing field are the first to admit that fundamental terms are often used indiscriminately and that something should be done about it. And yet it is surprising to find that within the field itself they seem to understand each other reasonably well. Three different people may use a word such as "paint" in three different ways, but somehow each one knows what the other two are talking about. To someone on the fringe of or outside the field, however, it gets quite confusing.

In this manual an attempt has been made to use words and terms—and their definitions—in the way most widely accepted by the finishing field. Too, the terms are defined as encountered and then used only in that one sense. For example, the term "paint" is used broadly in the finishing field to refer to any and all organic finishes. It is also used to refer to one specific type of organic finish. Here it will be used only in reference to a specific kind of organic finish.

There are two principal reasons for putting organic coatings on metals. One reason is to make the product pleasing in appearance; to give it the finishing touch that makes it more attractive and more presentable than it would be without the finish. Another reason is to protect the base metal against corrosion from such things as moisture or chemicals. These are the two most important reasons for using organic coatings on metals, and we will only concern ourselves about them in this manual.

Besides protection and decoration, there are several other uses of organic finishes that should be mentioned. They are used to provide surfaces that are easily kept clean for sanitation purposes; to obtain better light reflectance; and, for such things as promoting safety through use of colors.

Organic finishes are engineering materials. They are rightly classed as such, because they have, like all engineering materials, a definite function to perform. Thus, while the metal of which a product is made may resist stresses of various kinds, the coating must resist corrosive conditions. In fact, the performance of many industrial and consumer products is directly dependent on organic finishes. Take, for example, food and chemical containers where the primary requirement for successful performance is a coating that will protect the metal from corrosion or prevent the metal from contaminating the contents in the container.

Because they are engineering materials and serve definite functions, organic coatings should be selected with the same care that is used in picking the other materials that go into a manufactured product. They should be planned for as part of the structure at the same time as the other materials.

A few words should be said here about the place of organic coatings in the overall metal finishing field. Among the competitors for the finishing dollar there are a number of other kinds of coatings used on the surfaces of metals. There are metallic coatings, employing any of the common nonferrous metals, like zinc, cadmium, tin, nickel, chromium, copper, lead and aluminum. There are also a variety of chemical surface treatments in which the metal surface is converted to a corrosion resistant film. And there are coatings of inorganic materials, such as vitreous enamels, cement and clay products. All of these have their advantages and limitations. It isn't within the scope of this manual to make detailed comparisons between them. However, a few outstanding comparisons can be made.

From the standpoint of versatility and range of use, organic finishing surpasses the other methods of metal finishing. Organic coatings can be applied satisfactorily to practically all common metals and to all shapes of products. Their range of color and gloss is practically unlimited, which makes them extremely desirable where appearance and attractiveness are primary considerations.

In protection against corrosion, organic coatings are superior in some cases and inferior in others to metallic coatings. They cannot, for example, compete with metallic coatings like nickel and chromium plating, in this respect; although where possible they would be used in preference to these metallic coatings because of their lower cost. In many applications clear organic finishes can be applied over plating to further improve corrosion resistance. On the other hand, organic coatings are usually higher in corrosion resistance than chemical surface treatments. And, finally, in respect to such properties as hardness, toughness and flexibility, organic coatings compare favorably with some metallic coatings and less favorably with others.

In the final analysis, it depends upon the particular job to be done. The following sections will try to give the range of characteristics, properties and usefulness of organic coatings so as to provide a general working knowledge of them and better compare them with other coatings for metals.

Principal Types of Organic Coatings

Type	Vehicle	Pigment	Principal Drying Methods
Enamel	Varnish and/or resin	All colors	Oxidation and/or polymerization
Lacquer	Nitrocellulose with/or without other resins and plasticizers	Unpigmented or colored	Evaporation
Varnish	Resins combined with drying oils	Unpigmented	Oxidation and/or polymerization Evaporation
Paint	Drying oils	All colors	Oxidation

The Selection Problem

Like all materials-selection problems, choosing the right organic finish for a product is always a compromise. While it is desirable to get a coating that will meet completely all requirements, it is usually found that there is no such ideal coating, and that sacrifices must be made of some properties to gain others.

In selecting organic coatings it is advisable to consult with organic coating manufacturers. They are experts in their field and are prepared to help choose the coating that will do the best job. In some cases standard finishes from stock will be satisfactory; in other instances a special formulation may be necessary. But in any case, from the vast number of organic finishes available, it is usually possible to get a finish that has a surprising number of the properties required for the job.

There are a number of questions that must be considered in solving the selection problem. The six major ones are:

1. What kind of metal is being coated and what is its surface condition?
2. What appearance is desired?
3. What corrosive conditions must the coating protect against?
4. How durable must it be—that is, what are the service conditions, in addition to the corrosive conditions that must be met?
5. How is the coating to be applied and then dried?
6. Cost?

Kind of Metal and Surface Conditions

Regardless of the function the organic coating is to serve—whether it be decoration or protection—it must adhere well to the underlying surface. All organic coatings do not adhere equally well to all metals and alloys. So it is the property of adhesion which is most important to consider in relation to the metal being coated.

The adhesion of coatings varies considerably with various types of metals. A coating which is suitable for iron or steel may flake or peel in a short while when used on aluminum, zinc or some other metal. It is most important for the initial coating or primer, since it is in direct contact with the surface, to have good adhesion properties on the particular metal being coated. In subsequent coats the adhesion characteristics with respect to the metal are of relatively minor importance, while adhesion of the various coats to each other is of major importance. Details as to the finishes which adhere best to each of the common metals and alloys will be given under the section on primers.

The condition of the surface being coated is extremely important in obtaining good adhesion. Both the physical texture and cleanliness must be considered. Highly polished surfaces cause more adhesion difficulties than rougher surfaces. Thus, where polished surfaces are being coated the finish must be designed with extra adhesion qualities.

Practically all metal surfaces are covered with layers of foreign matter of one sort or another. It may be rust, mill scale, surface compounds, dirt and grease. Very often they are present in very thin invisible films. For optimum adhesion these contaminants must be removed. Where they cannot be removed or are not removed before coating, the compatibility of the coating material with the contaminants largely determines the degree of adhesion obtained.

The preparation of surfaces before applying organic finishes is a large and important subject in itself, but it is not within the scope of this article. However, in passing, it should be emphasized that surface preparation is as important to the performance of the finish as the coating itself.

Decorative Considerations

The decorative qualities that should be considered in selecting a finish are the color, the brightness, mass tone and cleanliness of the colors, the gloss, the color retention, and the hiding power or opacity. Where unique effects are desired, such as in wrinkle or hammered finishes, those effects are, of course, a major consideration.

Color selection and gloss depend largely upon the use to which the part will be put. If it is a consumer item it invariably will need sales appeal. Bright and pleasing colors will probably be selected. If the parts are to be handled frequently, dark or dull finishes may be preferable to light, glossy ones. Where industrial items are involved, the selection of color and gloss should be made primarily from the standpoint of utility and ease of cleaning. It is difficult to get specific on the matter of color and gloss, because the choice of color or color combination is practically unlimited. Most organic coating manufacturers can provide a wealth of information about colors and their proper use.

Color retention is an important property to consider, because not only is the initial appearance of the finish important but also how long the finish remains attractive under normal service conditions. Some colors are more likely to "fade" than others. Where white finishes are involved, the non-yellowing properties are especially critical. They are particularly susceptible to such things as cooking fumes and tobacco smoke. Color retention depends to a large extent on the exposure conditions, the pigment used for coloring the coating, and the vehicle.

Hiding power or opacity refers to the ability of a coating to obscure previous coats or the base metal. The hiding power characteristics are important because they influence the number of coats required. The hiding power of a coating is usually determined for the film thickness that has been selected to meet the durability requirements.

Protection Characteristics

The protection of the base metal against corrosion afforded by an organic coating is probably its most important single property. Organic coatings prevent corrosion in three ways. The simplest of the three is mechanical protection in which the coating isolates the metal from corrosive agents, such as the atmosphere or chemicals. To be most successful, the surface of the metal must be completely covered and the film free of pores. Thus, coatings that protect by mechanical means are used only where complete coverage is assured and where accidental puncturing of the film is unlikely.

The second way of protecting against corrosion involves the use of corrosion inhibitive pigments. They are probably the most used of the three types, because they are not as sensitive as the mechanical type of film to small breaks, nor does moisture impermeability have to be as complete. They have a certain passivating action on the surface of the metal which increases the metal's corrosion resistance. The third method has somewhat limited use. It involves the use of pigments that give electrochemical protection to the base metal.

It is, of course, obvious that before the base metal can be protected the coating itself must be capable of resisting the effects of corrosive agents. Thus, not only must the pigment be considered but also the vehicle that will bind the pigment to the surface. In some applications a clear finish is desired, such as in food containers; in such cases the vehicle alone must resist corrosive attack from the chemicals involved.

Durability Factors

Besides the things already mentioned, there are still a number of other characteristics that affect the life of the coating. In most applications it is not enough to have a finish that will be attractive and afford protection against corrosion. It must also be capable of standing up under other service conditions. These other desirable properties include wear and abrasion resistance, toughness and flexibility, chip resistance, and heat and cold resistance. Not all these properties are required in any given application, but usually at least several are involved.

Processing Considerations

The cost of applying an organic coating is usually many times greater than the cost of the coating material. Because of this, the methods that can be used to apply and subsequently dry a given organic coating are important considerations in the selection picture.

Methods of Application—Organic finishes can be applied by the following methods: brush, spray, dip, roller coat, flow coat, knife, tumble, silk screen, and electrostatic means. Of all these, application by brushing is the slowest. All the others are production methods. Whatever method of application is used, the coating material that is selected should have characteristics most suitable for that method. If the coating material is to be sprayed, it should, for example, spray easily with good atomization and the spray should be sufficiently wet to give satisfactory leveling of the applied film. For dipping application, the coating should give a uniform film thickness and not sag or run excessively; and

Check List of Selection Factors

Reproduced here is a typical report blank used by organic coating manufacturers to obtain the data necessary to select the proper finish for any particular job.

ARTICLE FINISHED

Dimensions.............Wood.............Metal.............Kind...............
Interior or exterior exposure.........Expected durability.........

PREPARATION OF SURFACE PRIOR TO PAINTING

Bonderized........Degreased........Alkali wash........Sand blast........
Chemically cleaned........Solvent wipe........Other method........

APPLICATION

(1) Brush................................Open time................................
(2) Spray......Kind of gun......Pressure at tank......At gun......
Type of head, needles and nozzle..........................
(3) Dip—Consumption per day....(Gallons) Length of flow....
Size of tank.......................Operating temp.......................
Is it covered when not in use?..........How agitated?..........
Speed of withdrawal?...............Mechanical lift?...............
Hand-dipped?...............
(4) Roller Coat—Pfund film reading................................
Object fabricated.............How soon fabricated?.............
Is lithography and printing applied over the top?...........
Is finishing varnish applied over the top?.........................
(5) Flow Coating—Length of flow................................
(6) Knife..
(7) Tumbled..
(8) Silk Screen..
(9) Electrostatic..

REDUCTION

% Reduction....Reducer....Gravity at which material is used....
Viscosity desired...........Temperature type viscometer...........

GLOSS

Full...............Semi-gloss.............Eggshell.............Flat...............

AIR DRY

Out of dust....To touch....To handle....Recoat....To wrap....

BAKING

Drain or air-dry time before baking......Baking temperature......
Time to reach this heat..
How long held at this temperature.................................
Is oven automatically controlled?..
How is temperature indicated?..
Cooling—Time elapsed between conveyor and assembly or packing.........
Type Oven—Gas..........Direct..........Indirect..........Electric........
Oil.........Steam.........Infra red.........
Conveyor.................................Stationary.................................

SHOP CONDITIONS—

How is product wrapped? or packed?....................................
How soon?...........Print resistance, psi.....................................
Time....................................Temperature...............................

This Item Used in System as Follows:..
....
....

for flow coating, viscosity and solvent evaporation rate are the most important properties.

The time required for the finish to set up is another processing factor. A quick setting material usually gives a cleaner finish, because it will not hold dust particles. However, setup should not be so fast that proper film leveling will not take place. Where a multi-coat system is used the undercoats may require good sanding properties. Also, good adherence properties between coats is essential. Too, it is sometimes desirable to use a coating on which minor finish repairs can be made after assembly with air dry or low temperature drying materials.

Finally, the finish should be able to withstand the normal handling encountered in production and assembly operations. This involves the properties of mar resistance, hardness and flexibility.

Drying Organic Finishes—In production finishing, drying the coating after it has been applied to the product is of utmost importance. More than any other factor, it determines the speed at which the products can be finished. Organic coatings dry by one or more of the following methods (termed "drying mechanisms"): (1) evaporation or loss of solvent, (2) oxidation, and (3) polymerization.

When a coating material is applied to a surface, the first thing that takes place is evaporation of the volatile ingredients, which are almost always present in at least a small amount. Some finishes, such as lacquers, dry completely by evaporation of solvents. This evaporation process can be accomplished at normal or at somewhat elevated temperatures. Thus, ordinary air drying is generally used; in some applications a forced air system may be used to drive off the solvents and reduce drying time.

After evaporation of the volatile ingredients, those finishes that do not dry solely by evaporation are still in a semi-fluid state, and they depend upon either oxidation or polymerization, or a combination of both, to convert to their final hard form.

In drying by oxidation, the oxygen from the air combines with certain constituents of the coating, which results in the hard film formation. Sometimes subsequent polymerization is also promoted. Coatings that harden by oxidation are usually dried at room temperatures. In general, it is the slowest of the three methods. The coatings usually do not achieve optimum hardness for many days. The oxidation reaction continues in a reduced degree during the life of the finish, so that oxidizing finishes may eventually disintegrate through this "extension" of the drying process. However, many interior oxidizing coatings last years without visible effect.

Polymerization also involves a chemical reaction. Briefly, the reaction can be described as the chemical linkage of small molecular units to form much larger molecules. This can occur at normal or at elevated temperatures either in the presence or absence of oxygen. However, polymerization is speeded-up by the use of heat, so most finishes that dry chiefly by this method are dried by baking at temperatures up to as high as 400 F.

Cost

Whenever possible organic finishing materials should be purchased on the basis of coverage per gallon rather than price per gallon. In other words, the cost of the coating should be figured as the cost per sq. ft. of coverage. For example, a low priced coating may have lower coverage per gallon than a more expensive one, so that in the final analysis the more expensive coating material may prove to be more economical.

As has been pointed out before, the ap-

Many modern finish formulations are designed to serve in conjunction with accelerated drying methods. (Photo: Courtesy Despatch Oven Co.)

plication and processing properties are important considerations in the over-all cost picture. Thus, if an air-drying finish will serve the purpose and there is no production-line problem, it would be preferable over a baked finish which required considerable outlay in equipment and operating expenses. On the other hand, if fast production and high output is required, a baked finish or a rapid drying lacquer would be more economical than a slow air drying finish.

The life of the product being coated must also be considered. Refinishing is an expensive operation because of the time and labor involved, so high quality finishes with high durability should be selected where long term service is required, even though such coatings cost more. But where only a relatively short life is expected, the finish should be selected accordingly.

Composition of Organic Finishes

Organic finishes are made up to two principal components: a vehicle and a pigment. The vehicle is always there. It contains the film-forming materials which enable the coating to convert from a mobile fluid to a solid film. It also acts as a carrier and suspending agent for the pigment. A pigment may or may not be present, but usually is present in protective coatings for metals. The pigments are held in suspension in the vehicle. They are the coloring agents and, in addition, contribute a number of other important properties to the finish.

Vehicles

Vehicles are made up of film-forming materials and various other ingredients, including thinners (volatile solvents) which control viscosity, flow and film thickness, and driers which facilitate application and improve drying qualities. We will concern ourselves chiefly with only the film-forming part of the vehicle, because it is that part of the vehicle which to a large extent determines the quality and character of an organic finish. It determines the possible ways in which the finish can be applied and how the "wet" finish will dry to a hard film; it provides for adhesion to the metal surface; and it usually influences the finish's durability.

Vehicles can be divided into three main types: (1) oil, (2) resin, and (3) varnish. The simplest and among the oldest vehicles are the straight drying oil types. Resins, as a class, can serve as vehicles in their own right, but are perhaps more often used with drying oils to make the varnish type vehicle. Varnish vehicles are composed of resins and either drying or non-drying oils, together with required amounts of thinners and driers. Although their principal use in metal finishing is as a vehicle to which pigments are added to make paints or enamels, they are also sometimes used in their own right as a metal finish. For this reason they are often classified as a full-fledged organic finish along with paints, enamels and lacquers. A discussion of them will be left until we take up the principal types of organic finishes. Next, we will discuss the film forming ingredients — drying oils and resins — that make up the three types of vehicles.

Drying Oils

Vehicles consisting of oil only are used to a very limited extent in metal finishes. Oils are confined almost entirely to maintenance and structural steel paints. Even in these fields varnish type vehicles are being used to a considerable extent. But since drying oils are commonly used in varnishes, a brief listing of some of them is warranted.

Linseed oil is the most important drying

oil in use at the present time. There are a number of different kinds that differ in rate of drying, and in such properties as water resistance, color and hardness.

Tung oil or China wood oil, when properly treated, excels all other drying oils in speed of drying, hardening, and water resistance. Oiticica oil is similar to tung oil in many of its properties.

Dehydrated castor oil dries better than linseed oil, but slower than tung oil. Some of its advantages are good color and color retention, and flexibility. The oils from some fish are also used as drying oils. If processed properly they dry reasonably well and have little odor. They are often used in combination with other oils.

Perilla oil is quite similar in properties to fast drying linseed oil. Its use is largely dependent upon its price and availability. Soybean oil is the slowest drying in the drying oil classes, and is usually used in combination with some faster drying oil such as linseed oil.

Resins

For convenience, resins can be broken down into natural and synthetic types. A resin may come under one type or it may be a combination of the two. The natural resins come from the exudations of plants. Rosin is by far the most important one in use today. In its natural form it is obtained from pine trees. It is combined with many materials to form useful resins for organic finish vehicles. Other natural resins include the elemi, congo, kopal, and shellac resins.

Synthetics are man-made resinous materials, built up or synthesized by the union of simpler compounds. Because of the great variety of raw materials and the close control possible in their manufacture, most synthetic resins are superior to natural resins. Below, each of the principal synthetic resin "families" is discussed. In following this discussion it must be kept in mind that the resins are not necessarily used alone; they may be and very often are combined with each other in many different ways to give the set of properties desired. What we want to do here in discussing each resin is list the chief characteristics and properties which they contribute to the organic finishes whether they be used alone or in combination with other resins.

Phenolics—Phenolic resins are formed by various combinations of phenols and the aldehydes. They are widely used in organic finishes because they offer a broad range of properties to coatings.

As a group, phenolics have good durability and are high in chemical resistance to a wide variety of chemicals. They are impervious to moisture, and highly resistant to salt atmosphere. Phenolics, themselves, are dark in color and are subject to discoloration when exposed to sunlight. Thus, they have poor color retention and are limited to finishes of colors other than white. However, they can be modified for better color retention and for use in whites.

Phenolic resins can be classified under two broad groups, the 100% phenolics and the modified phenolic types. The 100% phenolics offer the optimum in durability, toughness, chemical and moisture resistance. Depending on their composition, they may or may not be soluble in drying oils. They form a variety of vehicles. Some are air-drying while others polymerize and harden with heat. One type of 100% phenolic is used in an alcohol solution as a baking lacquer.

The modified phenolics are modified with other resins such as rosin and ester gums or with drying oils. In general, their properties do not approach the 100% phenolics. A relatively recent advance is a group of phenolic dispersion resins that are modified phenolics dispersed in thinners. They dry to touch in about 5 min. entirely by solvent evaporation, giving an extremely durable finish. They have excellent adhesion to practically all metals and alloys. Another special group of modified phenolics are used in nitro-cellulose base lacquers to produce durable mar-proof finishes.

Finishes containing phenolics find wide use. In the packaging field they are used for lining food and beverage containers. The finishes are usually applied by roller coating methods on flat tinplate and cured before the cans are fabricated. Because of their good chemical resistance, phenolic finishes are used in tanks and equipment for shipping and storing chemicals. Being impervious to water and moisture, they are widely used in primers for structural steel and underwater structures, such as dams, locks and water tanks. They also are used in aircraft primers and as undercoats in two-coat paint systems.

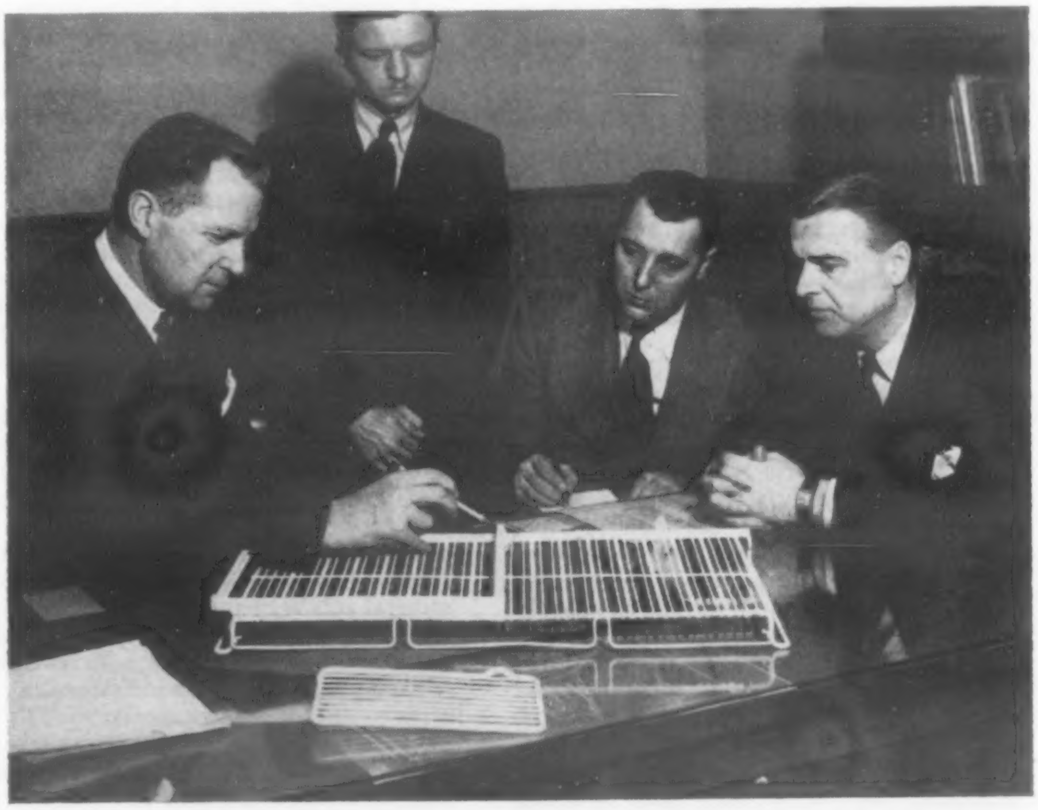
Alkyds—Alkyds are another important family of resins widely used in organic finishes. Ordinarily, alkyd resins are light colored, hard and tough, but insoluble in drying oils. To make them a more suitable finish ingredient, drying oils are introduced into the reaction. The oils combine chemically with the alkyd to form what are commonly called oil-modified alkyd resins. The type and amount of oil modifier may vary over a wide range; also, natural or synthetic resins may be added. Thus, there are available innumerable combinations.

Oil modified alkyd resin vehicles may be formulated to harden by any one or any combination of the three drying methods. The oxidizing or air-drying types can be used as the sole film former or in combination with other drying oils and resins. The nonoxidizing types are used as plasticizers in nitrocellulose lacquers and synthetic baking finishes.

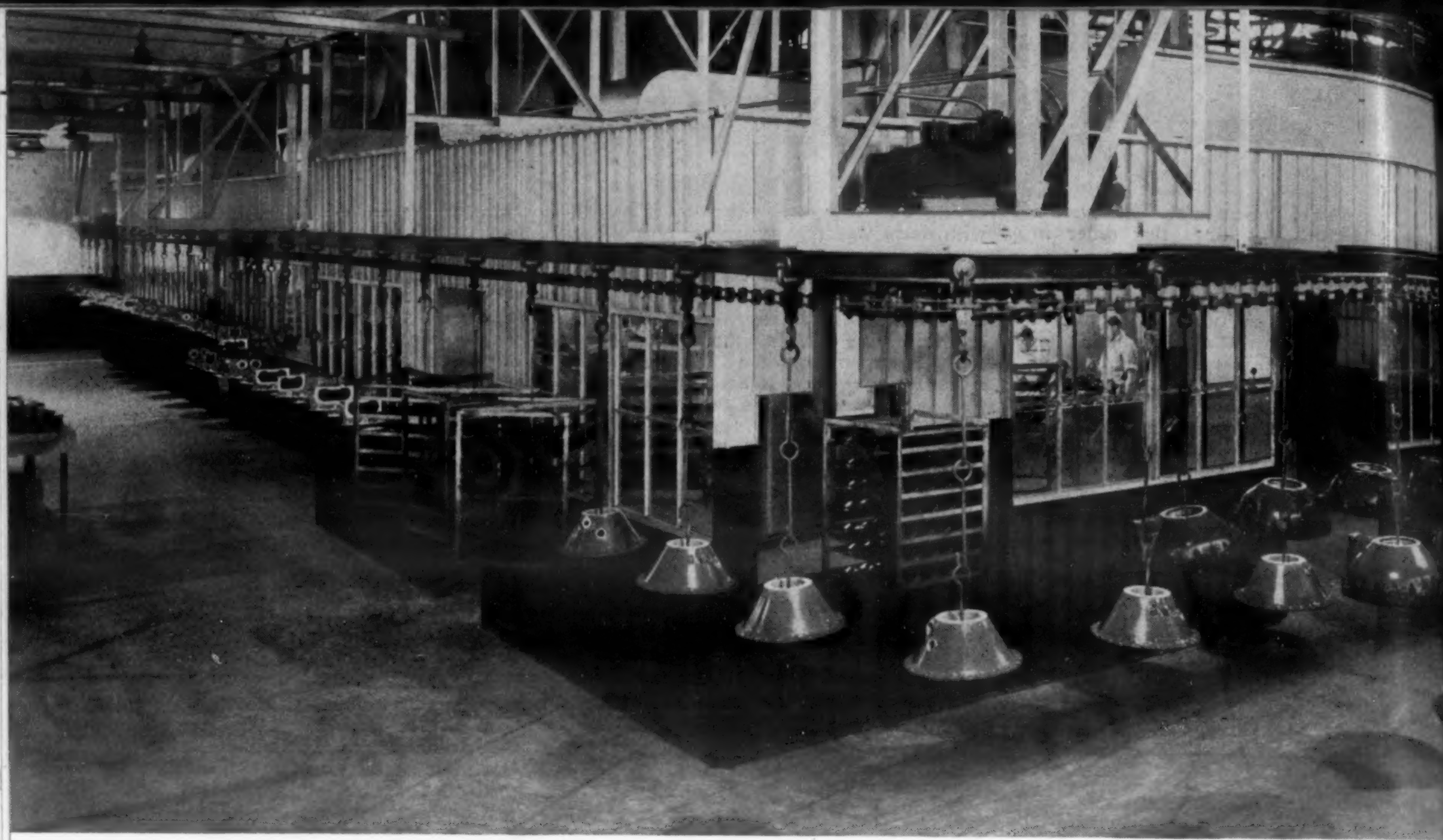
The outstanding characteristic of oil-modified alkyd vehicles is their excellent durability. They dry to tough, hard films that retain their flexibility and have high gloss and good color retention. In exterior durability they surpass all other types, including 100% phenolic resin types. One of the chief reasons for this is their high resistance to the destructive effects of ultraviolet light.

Oil-modified alkyd vehicles alone usually form a pale film. In enamels they have good color retention, this being somewhat dependent on the oil used. They also have good oil resistance, but where strong alkalies are concerned the phenolics, in general, are better.

Formerly, one of the most important uses of this class of resins was in automobile finishes to replace the lacquer type finishes. They were more durable and more economical and the drying was speeded up through the application of heat. However, since then alkyds have found wide use as additions to lacquers. Thus, they are largely responsible for many of the recent improvements in lacquers, including higher solids, higher build and gloss, lower solvent costs, improved color



Production, sales and design engineers often confer on the finishing material for a product to make certain it will satisfy all demands. (Photo: Courtesy Servel, Inc.)



retention, and durability. Other typical uses of alkyd resin finishes are for household appliances, and architectural white finishes.

Ureas and Melamines—Urea and melamine are from the same plastics family and have similar characteristics. They are thermosetting, dry by polymerization and are, therefore, used exclusively in baking finishes. They give a water-white, hard film with good chemical resistance. Because of their brittleness, they are almost always combined with alkyds. In this combination they contribute fast baking time, hardness and mar-resistance; also, depending upon the alkvd used, they improve color retention.

The melamines in general are rated somewhat above the ureas. They are higher in cost, but are faster drying, more heat stable, and have better chemical resistance.

The melamines and ureas are used in baking enamel vehicles, for a variety of products, particularly where white or pastel tinted finishes are required. Typical applications are in household appliance finishes, such as refrigerators, stoves, and washing machines.

Vinyls—Where vinyl resins are employed in organic finishes they are almost always the sole film-forming ingredient. When used on certain metals, particularly iron, they must be plasticized and stabilized. Vinyls are carried in a volatile solvent and dry by solvent evaporation. However, the vinyl resins do not always release the solvent readily and sometimes must be baked to dry completely. Heating also fuses the film to surface, promoting better adhesion.

Vinyl resins are thermoplastic; they originally had low solids and high viscosity, therefore poor body and poor spraying characteristics. However, recent advances have gone far towards eliminating these inherent disadvantages. The resins are water-white, odorless, tasteless and non-toxic; for these reasons they are widely used for food and beverage containers. When properly plasticized, their films are tough and rubbery. They also have excellent resistance to moisture, acids and alkalies. However, their water resistance diminishes rapidly above 212 F. Because of their flexibility, vinyl coatings will stand rather severe forming operations. Their high chemical resistance suits them for use as stop-off lacquers in electro-plating baths, and for pipe linings and chemical storage and processing equipment. Since vinyl resins turn black if in contact with certain metals (steel, zinc, tin) during the baking cycle, it is necessary in coating these metals to apply them over a primer to avoid discoloration. However, as mentioned above, they may be stabilized to prevent discoloration.

Acrylics—The resin of this family most commonly used in metal finishes is polymethyl-methacrylate. It is a water-white, transparent thermoplastic resin soluble in organic solvents. The coatings in which it is used dry best by forced drying or baking. The main deterrent to its wide use is its high cost. Its most valued characteristic is high resistance to discoloration at temperatures as high as 500 F. Thus, its principal use is in white enamels for high temperature service.

Besides excellent color retention, this acrylic has good resistance to moisture, mineral oil, vegetable acids and other dilute acids, alcohols, and most chemical fumes. Because the clear film adheres well to polished surfaces, it is widely used on plated surfaces and to protect metals such as silver, zinc, copper, aluminum and stainless steels. Clear solutions of the resin are neutral, and are, therefore, often used in luminous paints as the binder for the phosphorescent pigments which are adversely affected by acidity and moisture.

If pigments are added to a clear acrylic resin vehicle, the film tends to be brittle, especially where pigmentation is high, and therefore must be plasticized.

Maleics—Maleic resins are very complex resinous materials formed from the reaction of rosin and glycerine with maleic anhydride added. They dissolve in most oils to form good drying, high viscosity vehicles that have good color and color retention, second only to the alkyds. In durability they compare favorably with the modified phenolics. Because of these characteristics they serve chiefly as a varnish ingredient in white as well as colored enamels. They are also an important component in many nitrocellulose lacquers.

Polystyrenes—In appearance the polystyrenes are basically colorless; they are tasteless and odorless and have good resistance to water and moisture, acids, and alkalies. Although they have excellent flexibility and wear and abrasion resistance properties, they are not particularly tough and lack good adhesion to metal. Because polystyrene solutions are high in viscosity and low in solids content, they tend to be stringy when sprayed. Polystyrene resins are used largely as blending agents with other film formers, and have wide use as an ingredient for lacquers and as vehicles for phosphorescent pigments.

Silicones—These resins are recent developments in the plastics fields. They are just beginning to be used as an ingredient in protective coatings. Their outstanding characteristic is resistance to extreme heat. Panels coated with a silicone bearing finish have been subjected to 600 F over long periods of time with practically no color change. Chemical resistance and durability are also excellent. They are extremely stable and resist outdoor weathering. The big disadvantage at the present time is their very high cost.

Organic Finishes for Metals

Modern organic finishing set-ups include spray booth, continuous conveyors, air conditioning, water curtains and exhaust systems to remove all paint fumes.

Pigments

Pigments are the second of the two principal components that make up most organic finishes. It has been pointed out previously that pigments are not always a necessary part. But in finishes for metals, in comparison to pigmented coatings, clear coatings find only limited use.

Pigments contribute a number of important characteristics to organic coatings. They, first of all, serve a decorative function; they give the coating color to make it pleasing to the eye. The choice of color and shades of color by use of one or combinations of pigments is practically unlimited. Closely associated with color is the hiding power function or their ability to obscure the surface of the material being finished. This property furnishes opacity to the dried film and largely determines the number of coats required to obscure a previous coating or an uncoated surface.

In addition, pigments may contribute to the protection afforded by the finish. In many primers, for example, the principal function of pigments is to prevent corrosion of the base metal. In other cases they may be added to counteract the destructive action of ultra-violet light rays. Pigments also help give body and good flow characteristics to the finish. Their presence makes it easier to coat uneven surfaces with a resulting smooth appearance. And, finally, some pigments may give to organic coatings what is termed "package stability"—that is, they keep the coating material in usable condition in the container until ready for use.

Some pigments provide a number of these characteristics, while others provide only a few and must be combined with others to attain all the desired properties. Thus, there are single pigment coatings and multi-pigmented coatings.

Pigments can be conveniently divided into three classes as follows: (1) white hiding pigments, (2) colored pigments, and (3) extender or inert pigments. It will not be possible in the short space of this manual to discuss the large number of pigments in these three catagories. We can only mention a few outstanding things about them. Later, when primers are taken up, a little more specific information will be given about some of them.

The quantity of white hiding pigments used in organic finishes exceeds by far the use of all other pigments. The reason for this is that they are used not only in white paints and enamels, but also in making white bases for the tinted and light shades. The important characteristic about the white hiding pigments, of course, is that they furnish opacity to the dried film, and so this is an important consideration. It varies in different types as well as in the different grades of the same type of pigments. Some may lean toward blue-white; others may tend towards yellow-white.

The colored pigments furnish the finish with both opacity and color. They may be used by themselves to form solid colors, or in combination with whites to produce tints. Many colored pigments, in addition to their decorative value, provide rust inhibitive properties. For example, red lead, certain lead chromates, zinc chromates, and blue lead are used in iron and steel primers as rust inhibiters.

There are two general classes of colored pigments. One class is the earth or ground colors; they are colored minerals, occurring as natural deposits. Earth colors are very stable and are not readily affected by acids and alkalies, heat, light, and moisture. The other class is the chemical colors, which are produced under controlled conditions by chemical reaction. Under this class the metallic pigments can also be included. Aluminum powder is perhaps the best known. It has the property of leafing in certain vehicles; this means that it floats to the top of the film and forms a continuous metallic film. Gold or bronze powders are similar to aluminum powder in this respect.

The chief functions of extender pigments in coatings are to help control the consistency, gloss, smoothness and filling qualities, and leveling and check resistance. Thus, the properties of particle size and shape, oil obsorption and flatting power are important selection considerations. Extender pigments are for the most part chemically inactive. They usually have little or no hiding power.

Undercoats

Having discussed in some detail the principal ingredients that go into organic finishes, this and the next section will go into specific types of finishes formed with these vehicle and pigment components. It is a difficult matter to find a generally accepted way of classifying the variety of organic coating types, and any method selected is arbitrary. For the purposes of this manual we are going to discuss them under two broad categories: undercoats, and top or finish coats.

This section will be concerned with undercoats, which are simply defined as those layers underneath the finish coats. The function of the undercoats is to serve as a base, and they bond the finish coats to the metal.

Primers

Perhaps the most important of the undercoaters are the metal primers. They are the first coatings placed on the metal (except for fillers, in some cases), and so the kind of metal being coated largely governs the type primer that can be used. In cases where chemical pretreatments are used, primer coats may often be unnecessary. Chemical pretreatments usually allow a wider selection of primers for a given metal.

Primers for industrial or production finishing of metals are of two distinct types:

air-dry types and baking types. The air-dry types have drying oil vehicle bases and are usually referred to as paints. They may or may not be modified with resins. They are usually sprayed and dry enough to allow recoating from 1 up to 24 hr. Being primarily oxidizing type paints, they are relatively slow-drying. They are not used as extensively as the baking type primers, which have resin or varnish vehicle bases and dry chiefly by polymerization. Some primers, known as flash primers, are being used. They are applied by spraying and dry by solvent evaporation within 10 min. They are then recoated with finish enamel and usually bake dried.

In practically all primers, whether they be air-dry or baking types, the pigments used exert a predominating influence on the coating. The pigments impart most of the anti-corrosion properties to the primer and, along with the vehicle, determine its compatibility and adherence with the base metal. Next we will consider some of the common metals and discuss the primer pigments and, in some cases, the vehicles suitable for them.

Iron and Steel—The oldest and perhaps still the most widely used pigment in structural and maintenance work is red lead. It also sees use in industrial or production metal primers but not as extensively as in the structural field. Lead and zinc chromates are used extensively. Zinc chromate, because of its relatively high cost, is usually used in combination with other pigments such as iron oxide. Efficient combinations use up to 50% zinc chromate. Red and black iron oxides also find use in primers for iron and steel.

Aluminum Alloys—As in finishing other metals, aluminum alloy surfaces should be thoroughly cleaned. Zinc chromate is a suitable primer pigment that is widely selected. Red lead and lead sulfate pigments should not be used. Zinc chromate pigment used with a polyvinyl butyral vehicle is highly satisfactory. The commonly used primers for aircraft are based on phenolic alkyd resin vehicle combinations.

Magnesium Alloys—They are more difficult to prime than aluminum due to adhesion difficulties caused by reactions between the metal and primer ingredients. The metal should always be given a chemical pretreatment, such as a short immersion in sodium dichromate and nitric acid. The use of zinc chromate in a tung oil-phenolic resin varnish has been found satisfactory; also, a polyvinyl butyral resin vehicle with zinc chromate.

Zinc Alloys—Zinc alloys also present priming difficulties. To improve the adhesion of organic coatings, phosphate treatments are usually essential. Zinc chromates, zinc dust and zinc oxide pigments have been most successful on zinc alloys. Galvanized surfaces are handled similar to zinc alloys; particular care must be taken to clean the surface thoroughly to get good adhesion.

Copper Alloys — Copper, brass, bronze and other copper alloys are usually difficult to prime satisfactorily. Here again zinc chromates in a polyvinyl butyral vehicle have been used quite successfully.

Cadmium and Others — Cadmium is probably the most difficult metal to coat. Zinc chromate in polyvinyl butyral vehicle is one of the few primers found to be successful. Metals plated with nickel, nickel alloys, and chromium seldom are coated with organic finishes, but when it is done specialty types are required. Often clear, unpigmented coatings are used to retain the original plated color.

Intermediate Coats

Besides primers there are three other kinds of undercoaters that may or may not be used, depending on the application. These are sometimes called intermediate coats; they are fillers, surfacers, and sealers.

Fillers can be applied either before or after the primer, but more often after the primer and sometimes after the surfacer coat. Their function is to fill in large irregularities in the surface or local imperfections such as dents, mars and deep scratches. They are usually putty-like substances, and a variety of materials is used. Their chief characteristics are: (1) Must harden with a minimum of shrinkage; (2) must have good adhesion; (3) must have good sanding properties; and (4) must work smoothly and easily under a knife or leather pad.

Surfacers are often similar to primers; they usually have the same composition as the priming coat, except that more pigment is present. Surfacers are applied over the priming coat to cover all minor irregularities in the surface and so provide for a smooth appearing finish coat. They must have good adhesion to the primer and have good sanding properties. Often low priced extender pigments, like talcs and soapstones, are used merely to extend the hiding pigments and to give filling and sanding properties. They are usually neutral in color and are quite porous.

Sealers as a rule are used either over the fillers or surfacers. The chief function of sealers is to fill up the pores of the undercoat to avoid "striking in" of the finish coats. Therefore, they must have good sealing action. This filling-in of the porous surfacer or sealer also tends to strengthen the entire coating system. The sealers when used over surfacers are usually formulated with the same type pigment and vehicle as used in the final coat. Thus, the selection depends largely upon the properties desired in the finish coat.

Finish Coats

Finish or top coats are usually the decorative part of a paint system. However, they usually also have a protective function. The primer coats may require protection against the service conditions, because although the pigments used in primers are satisfactory for corrosion protection of the metal, they are frequently not satisfactory as top coats. Their color retention towards weathering, or their physical durability may be poor. In other cases, the primer coats may have satisfactory durability, but lack decorative appeal. For these reasons, not only must the finish coats have a pleasing appearance, but should also provide some mechanical shielding to the undercoats and base metal. There are also one-coat applications where the finish coats are applied directly to the metal surface and, therefore, provide the sole protective medium.

The principal types of finish or top coat materials used in metal finishing are enamels and lacquers. Varnishes can also be used where a clear finish is desired, but they find their widest use in metal finishing as a vehicle for enamels. Paints find only limited use in production metal finishing. Besides these, there are a variety of specialty coatings.

Enamels

Enamels as a group are difficult to pin down. The term enamel is used to mean a lot of different things in the organic finishing field and often is used as an indefinite catch-all. For our purposes we will limit the term to finishes which are an *intimate* dispersion of pigments in a varnish or a resin vehicle, or in a combination of both.

Enamels may dry by oxidation at room temperatures or by polymerization at room or elevated temperatures. They often dry by both oxidation and polymerization. Thus, enamels can be formulated as either air drying or baking type finishes, depending upon the vehicle used. It is in the baking type enamels that significant advance has been made in recent years. Modern baking enamels are baked in the range of from 200 to 350 F; at these temperatures the drying time may go as low as 10 min., and enamels are reported that can be dried by infra-red at 300 F in 2 to 10 min.

It is difficult to get specific about enamels, because they vary so widely in composition, in color and appearance, and in properties. Many of their characteristics have already been indicated under discussions of the various synthetic resins that are used so extensively in enamels. So here we will talk about the main characteristics and uses they have as a class.

Enamels are available in all colors and shades. Although they generally give a high-gloss finish, there are some that give a semi-gloss or eggshell finish and still others that give a flat finish. But, nevertheless, their outstanding characteristic of fine pigment dispersion remains.

Enamels as a class are hard and tough and offer good mar and abrasion resistance. They can be formulated to resist the attack

of the most commonly encountered chemical agents and corrosive atmospheres. Since they have good adhesion characteristics by proper formulation, they can be used in applications where only one or two coats are desired without the use of a primer coat.

Because of their wide range of useful properties, enamels are probably the most widely used organic coating in the metal-working industry. One of their largest fields of use is for coating household appliances—washing machines, stoves, kitchen cabinets and the like. A large portion of refrigerators, for example, are now finished with synthetic baking enamels in the place of porcelain enamels. These appliance enamels are usually white, and therefore must have a high degree of color and gloss retention when subjected to light and heat. The enamel vehicles are usually a medium to short oil glyceryl phthalate varnish in combination with urea, melamine or urea-melamine resins.

Another large use of enamels is in the automotive field, and it is here where the liveliest competition exists between enamel and lacquer type finishes. Perhaps the biggest advantage of enamels is their ability to build up a full finish with less coats than required with lacquers. Although enamels in the past have generally proved less durable under long exposure to weather, recent developments in synthetics have put them on an equal or superior basis with lacquers in this respect. So it is very likely that synthetic enamels and lacquers will continue to share the automotive field.

Other products finished with enamels include railway equipment, office equipment, toys and sport supplies, industrial equipment, and novelties.

Lacquers

The word "lacquer" comes from the name of the "lac" resin, which is the base of common shellac. Lac resin dissolved in alcohol was one of the first lacquers and has been in use for many centuries. Nowadays, shellac is called spirit lacquer. It is only one of several different kinds of lacquers; these, except for spirit lacquer, are named after the chief film forming ingredient. The most common ones are cellulose acetate, cellulose acetate butyrate, ethyl cellulose, vinyl, and nitrocellulose. The last mentioned is the most widely used and, in general, the single word "lacquer" has come to refer to this finish, in which nitrocellulose is the essential ingredient. But you never can be quite sure. The metal closure people, for example, call practically all their clear finishes lacquer, even though a large percentage of them are varnishes that are high temperature baked.

A distinguishing characteristic of lacquers is that they dry by evaporation of the solvents or thinners in which the vehicle is dissolved. This is in contrast to oils, varnishes, or resin base finishes, which are converted to a hard film chiefly through oxidation and/or polymerization.

Early lacquers were quite low in solid or body (film-forming) content, which meant that the applied films were very thin. The films were also brittle and lacked adhesion properties. Modern lacquers have largely eliminated these shortcomings, and greatly improved gloss, body and durability have been attained by the introduction of synthetic resins and plasticizers.

Plasticizers are added to give the applied coating elasticity, flexibility and adhesion. They are usually either extremely high boiling solvents or special oils which lubricate and soften the film. Synthetic resins are added to give the lacquer more body, improve gloss and adhesion, and impart rubbing and polishing properties; they also sometimes act as plasticizers. A relatively recent development is lacquers which have exceptionally high solid content and which are fed to the spray gun at about 150 F.

The trend in lacquers seems to be towards high resin content. And as more and more resins are added, the gap between lacquer and synthetic type varnishes diminishes until finally you have what might be called modified synthetic air drying varnishes. They may dry chiefly by oxidation and/or polymerization. The ultimate in industrial organic finishes has been predicted as lacquer-enamel type finishes in which the ingredients will be carried in a volatile solvent and which will dry instantly by burning off the solvent.

Lacquers normally dry hard and dust-free in a very few minutes at room temperature. In production line work, forced drying is often used. It is possible, therefore, to do a multi-coat job without having to lose time between coats. Where optimum hardness is desired, it is usually necessary to allow for overnight air drying. Because of the speed of drying and the fact that they are permanently soluble in the solvents used for application, lacquers usually are not applied by brush. Spray application or dipping are the usual procedures. However, there are some lacquers made suitable for brushing; they use a maximum amount of dilutents.

Lacquers on the whole are quite versatile in their properties and appearance. They can be either clear and transparent or pigmented, and their color range is practically unlimited. Lacquers in themselves have good color retention, but sometimes the added pigments, modifying resins and plasticizers may adversely affect this property.

Lacquer finishes are hard and mar-resistant. There is some difference of

The choice of organic finish for magnesium depends, among other things, on whether service is to be indoors, outdoors or in marine atmospheres. (Photo: Courtesy Dow Chemical Co.)

opinion about their adhesion to metals. Inherently, they lack good adhesion to metal, but recent developments in lacquer formulation have greatly improved their adhesion properties. By proper formulation, lacquers can be made to be resistant to a large variety of chemicals, including water and moisture, alcohol, gasoline, vegetable, animal and mineral oils, mild acids and alkalies.

Because of the volatile solvents, lacquers are inflammable in storage and during application, and this sometimes limits their application. However, the fire hazard of lacquers is often over-stressed. Practically all organic finishes also contain volatile solvents in various degrees which make them inflammable, although it is true that once ignited, lacquers burn more vigorously and the fumes are toxic when inhaled.

Because of their fast drying speeds, lacquers find wide application in the protection and decoration of products which can be dipped, sprayed, roller coated, or flow coated. They are especially advantageous for coating radios, metal hardware and fixtures, toys and other articles which, because of volume production, must dry hard enough to handle and pack in a short period of time. Lacquers are still widely used in automobile finishing and especially for refinishing autos and commercial vehicles where fast drying without baking equipment is a requirement. Lacquers also compete with enamels for coating metal stampings and castings, including die castings.

Unpigmented lacquers do not find much use for metal protection, although they are sometimes applied to polished metal surfaces to prevent tarnish, to heighten their luster, and to provide moderate protection on indoor exposure.

Besides the modern nitrocellulose lacquers to which most of the above discussion refers, several other types of lacquers are used to meet special requirements. Cellulose acetate lacquer is less flammable than nitrocellulose and is used where this is a critical factor. However, it has poorer moisture resistance than nitrocellulose and there are only a few resins and plasticizers with which it is compatible.

Cellulose acetate butyrate lacquer is similar to cellulose acetate, but has somewhat better moisture resistance. Ethyl cellulose lacquer has high dielectric strength, good heat stability, and remains flexible at low temperatures. It is used extensively as a wire coating.

There are several polymers of vinyl compounds which can be dissolved in certain solvents to give lacquers. They have essentially the characteristics and properties listed elsewhere under a discussion of the vinyl resins.

Varnishes

Varnishes consist of resins and either drying or non-drying oils. They are clear and unpigmented and can be used alone as a coating. However, their major use in metal finishing is as a vehicle to which pigments are added, thus forming other types of organic coatings.

The most important varnishes used in metal finishing are: (1) those composed of natural or synthetic resins dispersed in an oil; and (2) those composed of oil-modified alkyds. The oil-modified alkyd varnishes differ from the other varnishes in that the alkyd resin combines chemically with the oil.

The drying mechanism of varnishes all follow the same general pattern. First, any volatile solvents that are present evaporate; then, drying by oxidation and/or polymerization takes place, depending on the nature of the resin and oil. At high temperatures, of course, there is more tendency to polymerize. So varnishes can be formulated for either air or bake drying. Varnishes may be applied by brushing or by any of the production methods.

It is evident that with the large variety of raw materials to choose from and the unlimited number of combinations possible that varnishes have an extensive range of properties and characteristics. As pointed out before, they are unpigmented and clear. They range from almost clear white to a deep gold; they are transparent, lacking any appreciable amount of opacity. Japan, a hard baked black-looking varnish, is an exception. It is opaque, due to carbon and carbonaceous material being present.

There are some distinctions in properties between oil-modified alkyd varnishes and the other types. In general, oil-modified alkyds have better gloss and color retention and better resistance to weathering. They form a harder, tougher, more durable film and dry faster. On the other hand, they have less alkali resistance than the other varnishes. In such things as adhesion and rust inhibitiveness there is no distinctive difference.

The major use of varnishes, as coatings in their own right, is for food containers, closures such as bottle caps, and bandings of various kinds. Another large application is as a clear finish coat over lithographic coatings.

There is one other group of varnishes often termed spirit varnishes that are perhaps more accurately classed as lacquers for two reasons. First, they dry solely by evaporation, and second, they may be pigmented as well as clear. These spirit varnishes or lacquers have already been discussed under the section on lacquers.

Paints

Paints are a dispersion of a pigment or pigments in a drying oil vehicle. They have only limited use as finish coats for metals. Their principal use in metal finishing is for undercoats, and specifically for metal primers; these have been previously discussed. Paints dry by oxidation at room temperatures. Their rate of drying is slow as compared to enamels and lacquers; this is one of the reasons for their limited use in production finishing work. Another reason is that they are relatively soft and with age they tend to chalk and weather away due to this chalking.

Specialty Finishes

Almost an infinite number of specialty or novelty finishes are available to the metal products producer. Most of them are really lacquers or enamels to which special ingredients have been added or which are processed in some unique way to give the effects desired.

One of the most common groups of special finishes today are those giving a roughened or wrinkle appearance. These finishes are highly popular because they effectively cover up slight defects in the base metal and are highly durable. Wrinkle finishes are obtained by use of high percentages of driers which cause the wrinkling when the finish is baked. There is another group of specialty finishes which give a crystalline effect. They are enamels in which impurities are purposely introduced during the baking process by retaining the products of combustion in the oven while the coating dries. The wrinkle and crystalline finishes are widely used on instrument panels, office equipment and a variety of other industrial and consumer products.

Another widely used specialty for industrial and consumer items is a finish that gives the effect of hammered metal. This effect is achieved through special formulations or by causing the coating to spatter by a second spray coat. Other unusual finishes are now being obtained by adding special ingredients to lacquers to give them a stringy or "veiled" appearance when applied by spraying. The application of the silk-screen process to organic finishing of metals has also resulted in unique finishes with multi-colored effects.

Lithographic coatings are still another large group of specialty finishes. They are essentially enamels and vary widely in composition; they are applied to metals by printing processes and then baked. They are used extensively on sheet metal containers and other small objects, such as toys and novelties. The background coating is applied on the flat stock by roller coating before it is formed into its final shape. Since these coatings must undergo forming operations, they must be fairly flexible or elastic. The latest lithographic coating materials contain wax which comes to the surface when the finish is baked. Then, during the forming operation, the wax serves as a lubricant under the dies.

The war stimulated the development and use of luminescent and phosphorescent coatings which are visible in the dark. The introduction of new special pigments for these coatings has increased their use. These pigments have added suspension properties so that grinding is not necessary. Also during the war, a number of special cable and wire coatings were developed for resisting high temperatures as well as subzero conditions.

Acknowledgment

The following organizations, through their literature and personal help, supplied much of the information for this manual:

Bakelite Corp.
Ferro Enamel Corp.
General Electric Co.
Glidden Co.
Hercules Powder Co.
Interchemical Corp.
National Lead Co.
Pittsburgh Plate Glass Co.
Sherwin-Williams Co.
Watson-Standard Co.

Egyptian bronze relics date back to about 1500 B. C.

Ancient French bronze vase, probably over 2000 years old.

Old Bronze Anchor

recently dredged up from Monterey Bay, California, where it had lain in salt water for over 300 years.

Bronze

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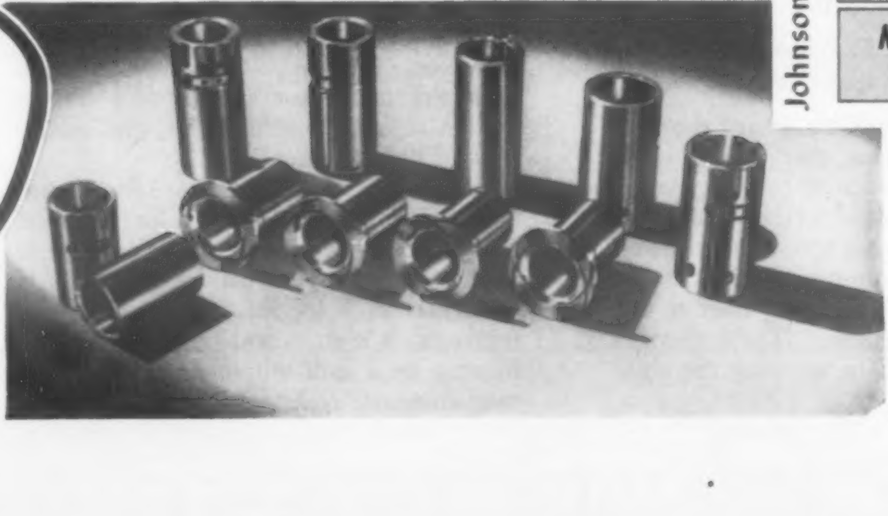


Johnson Bronze Sleeve Bearings as used in outboard motors.

Engineering Shop Notes

Aluminum Welding Without Deoxidizing

The question is often asked: Can aluminum parts be spot welded without first removing the oxide coating on the aluminum? The answer is that aluminum is being spot welded satisfactorily without prior removal of the oxide film. However, whether or not you can do so without trouble depends entirely upon your welding equipment, its adjustment and the strength and consistency that you require in your welds.

Welding equipment manufacturers in general do not recommend attempting this if your work requires uniform welds of maximum strength. However, you may be able to use additional welds. Or perhaps the strength obtained is sufficient for your job. If so, you can certainly make an appreciable saving by elimination of the work involved in deoxidizing or precleaning.

Equipment manufacturers report that use of a preheat current immediately preceding the welding cycle appears useful. Additional electrode pressure is also helpful. Electrode life may be low. It should be pointed out, however, that it will not be possible to obtain consistent, high quality welds without deoxidizing.

—From *Technical Advisor,* Reynolds Metals Co.

Why Dies Break

by David R. Edgerton, Lindberg Engineering Co.

To our way of thinking, two of the most important ingredients that go into the successful and satisfactory tool or die are common sense and experience. All too often most of us have occasion to call on these two stellar old-time virtues when "impossible" jobs are turned over to the heat treat department. These virtues should also be used in selecting the right steel for the job.

So how do we go about choosing the right steel? Let's take advantage of all the valuable experience and common sense in our respective organizations. We believe that only by close cooperation between the tool designer, the tool maker, the steel supplier, and the heat treater can errors in the specification of tool steels be minimized. Add to the experience of your own personnel, that of the steel supplier.

Every first-class reputable purveyor of tool steel maintains a service organization. Use their service and advice in the purchase of steel; and also use the experience and advice of your steel treater, whether he is in your own plant or is a commercial treater.

After cooperation, we feel that simplification is the most important item in choosing the right steel. Stick to a few standard types of tool steel and be very sure that every man in your organization is thoroughly acquainted with the uses, characteristics and limitations on those few grades. Except in a few very highly specialized shops, four types of tool steel: water hardening, oil hardening, high carbon-high chrome, and high speed will cover 95% of all requirements.

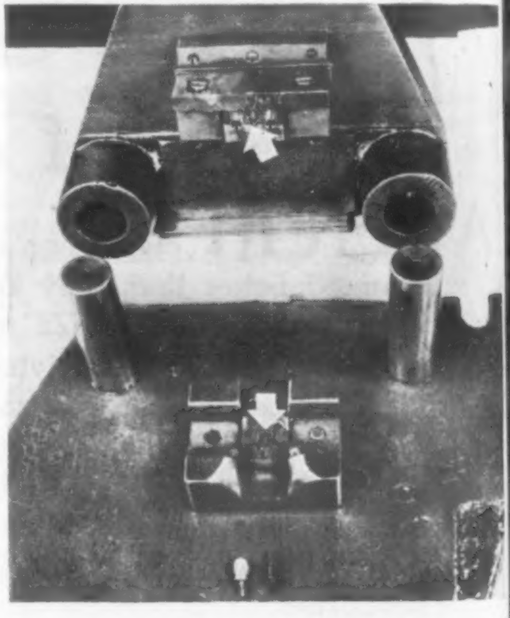
Beware of "Prima Donnas"! The term has been applied to "one purpose" steels. Don't misunderstand us. The prima donna does have its place and is fitted for jobs that no standard steel will handle, but we should use it as intended and not "louse up" production by trying to make the "Diva" sing bass, lead the orchestra, and take in the tickets, jobs for which she was never created!

Again, it is a sad frailty of human nature to follow the lines of least resistance in choosing a piece of steel for the job. How often have you heard: "We don't have that oil hardening tool steel that the designer specified on the print, so let's substitute water hardening, medium carbon alloy, or even cold rolled, and to heck with the poor heat treater who has to harden it and the tool maker who has to try and fit it and set it up."

And so, we add to our pleas for cooperation and simplification, one for patience. Don't use the wrong steel just because it is handy or cheap or easy to machine. It usually takes a lot longer to make up a replacement than to wait a few days for a forging or a mill shipment of the right steel from the right source.

Carbide Swaging Blocks Increase Die Life

In presses for swaging small parts, the swaging blocks should have high resistance to wear. The Underwood Corp., Bridgeport, Conn., in order to increase the wear life of their equipment for swaging or flattening small fulcrum posts used in business machines, adopted cemented carbide swaging blocks.



The white arrows point to the cemented carbide swaging blocks installed to increase wear life.

Originally these swaging blocks were made of hardened steel. About 10,000 cold rolled steel fulcrum posts could be swaged in a block before die reconditioning became necessary. Total die life ran between 25,000 and 30,000 operations.

Installing small cemented carbide swaging blocks, supplied by Carboloy Co., has eliminated all die maintenance. The blocks were still in use after 200,000 operations.

High-speed photographic studies of cutting tools reveal that a rake angle of approximately 24 deg. is more efficient than a more acute one when machining steel, according to L. T. Weller of General Electric Co. At the 24-deg. angle, the chip is rolled up with less crushing action and the chip flow is much smoother.

MATERIALS & METHODS Engineering File Facts

NUMBER 153
December, 1947

MATERIALS: Molded Plastics, Thermosetting

Molded Thermosetting Plastics Materials

General Properties and Uses

Type	Filler	Colors	Applications	Ft. Lb. per In. Notch Impact	Flexural Psi.	Tensile Psi.	Water Absorption % 48 Hr.	Heat Resistance Continuous F	Dielectric Str., V. per Mil Step by Step Test in Oil ⅛-In. Spec. 25 C	Dielectric 100 C	Spec. Gravity	Shrinkage In. per In.	Bulk Factor
Phenolic	None	Amber green, ruby, turquoise, tortoise shell	Milking machine parts and sterilizable equipment also used for hard synthetic jewels	34-0.44	10,000-14,000	7,000-8,000	0.1	248	250-300	70-100	1.28	0.009-0.011	2.25
Phenolic	Wood-flour	All colors except pastels	General purpose molding applications	0.30-0.40	9,000-12,000	6,000-8,000	0.5-1.0	248	300-450	60-125	1.33-1.45	0.006-0.009	3
Phenolic	Wood-flour	Natural and black	General purpose high-dielectric applications	0.28	10,000	7,000-8,000	0.8-1.0	248	350-500	100-200	1.33-1.35	0.007-0.008	3
Phenolic	Wood-flour	Natural and black	Parts requiring good water resistance, minimum odor	0.30-0.35	9,000-11,000	5,000-7,000	0.5-0.8	248	250	50	1.40	0.008	3
Phenolic	Wood-flour, graphite	Gun metal	Bearings, cams, caster wheels, etc. requiring reduced friction	0.30	8,000-9,000	6,000	0.8-1.0	248	—	—	1.42	0.007-0.008	3
Phenolic	Asbestos, wood-flour	Most colors except pastels	Heater plugs and insulating pieces requiring good heat resistance	0.30	9,500-11,000	6,000	0.2-0.5	392	250-400	50-80	1.67-1.80	0.005	3
Phenolic	Short fibre asbestos	Black and brown	Parts requiring better heat resistance and for low power arc resistance	0.30	9,000-10,000	6,000	0.01-0.1	428	250-400	50-80	1.80-1.90	0.003-0.005	3
Phenolic	Long fibre asbestos	Black and brown	Best phenolic for heat resistance, low moisture absorption, low coefficient of expansion, maximum dimensional stability	0.36-0.40	9,000-9,500	5,000-6,000	0.01-0.1	428	250-400	50-80	1.80	0.003-0.004	3
Phenolic	Asbestos, graphite	Gun metal	Bearings, slides, valves, cams, etc. requiring maximum heat-resistance, dimensional-stability, good wear resistance	0.28	8,000-9,000	6,000	0.01-0.1	428	—	—	1.75	0.003-0.004	3
Phenolic	Asbestos	Natural and brown	High-heat and high impact applications	0.50	10,000	6,500	0.3	428	125	50	1.80-1.85	0.002-0.003	6
Phenolic	Asbestos	Natural and dark tan	High heat-low flame, high impact applications	3.40	10,000	6,200	0.8	392	70-100	50-70	1.60-1.70	0.003-0.004	5
Phenolic	Mica	Natural and black	Electrical applications requiring improved heat and low-moisture absorption	0.30	8,000	6,000	0.01-0.05	428	300-500	150-300	1.88-1.92	0.002-0.004	2.5
Phenolic	Cotton flock	Most dark colors	General purpose molding material with improved impact resistance	0.42-0.60	9,500-12,000	7,000-8,500	0.8-1.0	248	250-300	60-80	1.36-1.42	0.003-0.006	4
Phenolic	Cotton flock	Black	Combines good water resistance, minimum odor and improved-impact resistance	0.52	10,000	6,500	0.8-1.0	248	125	40-50	1.42	0.004-0.005	4
Phenolic	Fabric-short fibre	Natural, black, red, brown	Medium-high impact material with good flow for complex sections	1.00-1.80	10,000-12,000	6,000-6,500	1.0	248	200-250	50-80	1.38-1.42	0.003-0.004	5
Phenolic	Fabric-medium fibre	Black, brown, red	High-impact material used for bulky sections	3.00-3.50	10,000	6,000-6,500	1.0	248	200-250	50-80	1.38-1.42	0.003-0.004	8
Phenolic	Chopped cord	Black	Highest-impact phenolic material. Cannot be used for some complex sections	5.0	11,000	6,200	1.0	248	300	70	1.35	0.003	8

(Continued on page 113)

MATERIALS & METHODS Engineering File Facts

NUMBER 153 ***(Continued)***

Molded Thermosetting Plastics Materials

Type	Filler	Colors	Applications	Ft. Lb. per In. Notch Impact	Flexural Psi.	Tensile Psi.	Water Absorption % 48 Hr.	Heat Resistance Continuous F	Dielectric Str., V. per Mil Step by Step Test in Oil ⅛-In. Spec. 25 C	Dielectric Str., V. per Mil Step by Step Test in Oil ⅛-In. Spec. 100 C	Spec. Gravity	Shrinkage In. per In.	Bulk Factor
Phenolic	Fabric, graphite	Gun metal	Cams, bearings, slides, etc. requiring high impact, reduced friction	0.70-0.80	8,000-9,000	6,000	0.8-1.0	248	—	—	1.45	0.003-0.004	4
Phenolic	Cotton flock and graphite	Gun metal	Cams, bearings, slides, etc. requiring medium-impact resistance, reduced friction	0.40	9,500	6,500	0.8-1.0	248	—	—	1.40	0.003-0.004	4
Phenolic	—	—	Used for the shielding of X-rays	0.30	9,500	6,000	0.5	248	—	—	—	0.005-0.006	3
Phenolic-Aniline	Wood-flour	Natural	Highest electrical properties with good arc resistance	0.30	10,000	6,000	1.25	248	300	300	1.34	0.006-0.008	3
Phenolic-Aniline	Mineral	Natural	Radio or similar parts requiring low dielectric losses. P.F. @ 1000 K.C. – 0.009	0.38	9,500	6,500	0.02	257	300-500	300-400	1.94	0.004	2.5
Phenolic-Aniline	Cotton flock	Natural	Highest electrical properties with improved-impact resistance	0.46	10,000	6,500	1.20	248	300	200-300	1.34	0.006-0.008	4
Urea	Cellulose	All colors including translucent and pastel shades	General purpose color work. Good arc resistance. Used for lamp shades, packages, radio cabinets, etc.	0.30	11,000	8,000	2.00	170	300	80	1.49	0.008	3
Melamine	Cellulose	All colors including translucent and pastel shades	General purpose color work with improved-temperature resistance. Good for dishes and buttons	0.28	12,000	6,000	1.7	210	230	250	1.50	0.008	3
Melamine	Mineral, cotton flock	Gray	Electrical applications requiring improved arc resistance. Excellent for ignition parts	0.44	8,000	5,000	0.25	284	300	200	1.80	0.006	2.5
Melamine	Fabric	Gray and black	Combines good impact resistance with improved-arc resistance	0.90	10,000	7,000	1.0	248	230	80	1.49	0.003-0.004	12
Cold Mold-Non-Refractory	—	Black and brown	Wiring device parts, cook-ware handles to withstand oven temperatures. Best cold mold for appearance	0.4	4,500	—	2.0	482	60	—	2.00	0.015	2.5
Cold Mold-Refractory	—	Gray	Arc deflectors, rheostat bases and other parts requiring maximum heat and arc resistance	0.6	5,000	—	0.05-15	1,292	60	—	2.20	Nil	2.5
Synthetic Hard Rubber	Mineral	Red	Electrical and ignition parts requiring good arc resistance and good dielectric at elevated temperatures	0.32	7,000	4,000	0.08	175	370	370	1.77	0.0195-0.0225	2
Mycalex	Mineral	Gray	Radio and other high frequency electrical applications requiring maximum heat and arc resistance. P.F. @ 1000 K.C. – 0.0023	—	10,000	—	0.0023	662	—	380	3.11	Nil	—
Mycalex	Mineral	Gray	General purpose electrical applications requiring low moisture absorption, high temperature and arc resistance. P.F. @ 1000 K.C. – 0.0018	—	12,000	—	0.001	482	—	325	3.70	Nil	—

* *Shrinkage. Molding materials shrink after they are molded. The values listed in the table give the amount of this shrinkage in in. per in. under average conditions. Allowance must be made in the mold design to compensate for this shrinkage.*

† *Bulk Factor. Mold designs must allow sufficient space for loading the molding compound. The ratio of the volume of compound before molding to the volume of the molded piece is called the bulk factor.*

Prepared from data submitted by the Shaw Insulator Co., Irvington, N. J.

MATERIALS & METHODS DIGEST

A selective condensation of articles—presenting new developments and ideas in materials and their processing—from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Progress in Metals Development Work

Condensed from Papers of the American Society for Metals

An important group of technical papers were presented at the annual meeting of the American Society for Metals in Chicago, October 20 to 24. There were 30 papers covering a variety of subjects, and as a whole they pretty well reviewed current progress in metallurgical development work. We have taken a number of these papers and digested them here. In later issues important papers presented before the other technical society meetings will also be digested.

High Temperature Alloys

Alloys for high temperature service are still the most sought-after engineering materials today. Two important papers were presented on this subject: one reported a new alloy, and the other supplied hitherto generally unavailable information about a standard alloy. A new cast alloy, designated as the "J" alloy, has been developed and was reported by Nicholas J. Grant of the Massachusetts Institute of Technology ("The Cobalt-Chromium J Alloy at 1350 to 1800 F," Paper No. 17). This new alloy uses the original cobalt-chromium-molybdenum base Vitallium as a starting point, and by additions of carbon up to a maximum of about 0.76% carbon, a large strength increase at high temperatures is possible.

The optimum carbon content was found to be 0.76%. At 30,000 psi. and 1500 F, this J alloy has a rupture life of about 500 hr. Thus, it shows better rupture properties in the range of 1350 to 1800 F than previous cast cobalt-chromium alloys. It is also stronger than any of the forged alloys at 1350 F for rupture times up to 1000 hr. and very much stronger at the higher temperatures for all test times.

In creep, the J alloy is about equal in performance to the other better known cast cobalt-chromium base alloys at 1500 F, but is poorer than nickel-chromium-cobalt-iron base alloys, such as N-155. At room temperature the lower carbon J alloys (0.40%) have a tensile strength of about 120,000 psi. and 10% elongation (in 1¼ in.) in the as-cast condition.

For those who must select, specify and use heat resistant materials, the paper by H. S. Avery and C. R. Wilks of the American Brake Shoe Co. ("Cast Heat Resistant Alloys of the 26% Chromium-20% Nickel Type," Paper No. 16) should be of invaluable assistance. This paper attempts to indicate the range of usefulness of HK cast heat resistant alloy (26% chromium-20% nickel).

The HK alloy probably has the best combination of properties for all-around high temperature service above 1600 F. It has better strength than the partially ferritic 26% chromium-12% nickel alloys of comparable oxidation resistance, and better scaling resistance than the balanced austenitic 24% chromium-12% nickel alloys of comparable strength. It has adequate carburizing resistance and better hot gas corrosion resistance than 16% chromium-35% nickel. Its alloy cost is slightly higher than 26% chromium-12% nickel and appreciably below that of 12% chromium-60% nickel.

For carburizing service, HK alloy can be fortified with silicon without seriously lowering hot strength. It is also suggested for service where maximum hot gas corrosion resistance is required.

Light Alloys

In the field of light metals, work continues on improving the ways and means of processing them. One of the major improvements in forming aluminum alloy parts for aircraft fabrication has been the development of the stretch press. A number of factors which influence the stretching of aluminum alloy sheet in this process were investigated by J. M. Taub of the Los Alamos Scientific Laboratory ("Stretching Characteristics of Aluminum Alloy Sheet," Paper No. 12).

The work covered primarily the simplest type of stretching problem: that of using a single contoured punch to form the sheet into a segment of a cylinder surface. The minimum strain, located in the area in contact with the punch, and the maximum strain, occurring in the unrestricted area between punch and gripping radius, were affected primarily by (1) the ratio of metal thickness to gripping radius, (2) frictional conditions as determined by type of lubrication, (3) temper of the metal, and (4) edge conditions.

The use of beryllium in magnesium casting alloys for reducing the tendency of magnesium alloys to burn was suggested by Jay R. Burns of the Air Material Command ("Beryllium in Magnesium Casting Alloys," Paper No. 10). Although present methods, using a salt-flux cover on the molten metal, are practical, economy and simplification would result from any decrease in the inherent tendency of magnesium alloys to oxidize when in molten condition. By adding beryllium in quantities of 0.001% or greater, it was found that there is a marked reduction in the tendency of magnesium alloys to burn. Thus, alloys containing beryllium may be held molten without fluxes and successfully cast in foundry sand containing no inhibitors.

Induction Hardening

In the past, induction hardening methods have not been applied very extensively to cast irons. This has been partly due to the lack of information on this phase of induction heating. Two papers were presented which should in some measure correct this situation. In a paper by J. R. Sloan and R. H. Hays ("Some Factors Affecting the Induction Hardening of an Alloy Cast Iron," Paper No. 5) the induction hardening of the bore surface of gray cast iron cylinder liners is discussed.

Since little information existed on the possible factors which might affect the cast iron alloy used for this application, the investigation was conducted to determine how the introduction of additional factors such as graphite flakes, pronounced segregations, and the presence of relatively large quantities of certain elements would influence induction hardening, as compared to steel. The effects of two frequencies, 3000 and 9600 cycles per sec., were compared and it was found that the higher frequency concentrates the heat energy input closer to the surface and thus increases surface temperatures and depth of case. In a medium carbon steel this overheating causes a grain growth and reduces the physical properties. In an overheated cast iron, these same effects occur; in addition, there is

DIGEST

some absorption of segregated alloys and resolution of graphite. This results in somewhat softer surfaces.

C. F. Walton, Meehanite Metal Corp., and H. B. Osborn, Jr. of the Ohio Crankshaft Co., reported on the induction hardening of Meehanite cast iron ("Induction Hardening of a Quality Controlled Iron," Paper No. 4). In production induction hardening of Meehanite, hardness values of 55 to 60 Rockwell C can be readily obtained, and the distortion is much less than by furnace heating. It responds to induction hardening as readily as any grade of steel, and better than many, due to its carbide dispersion.

Cases up to 0.100 in. in a 0.800-in. dia. and up to 0.200 in. on a 1.2-in. dia. do not weaken the full section strength. However, through hardening (maximum hardness without drawing) reduces the strength about 30%. To have any cast material perfect after induction hardening and finishing, it must be flawless because any minute defect, such as a microshrink crowfoot, will be readily apparent upon magnafluxing after hardening.

Grinding Hardened Steel Parts

That grinding of hardened steel parts induces residual stresses in the part is well known, but only in the last few years has it been shown that even where there are no cracks visible, the part may subsequently crack due to these stresses. In a paper by Howard E. Boyer of the American Bosch Corp. ("Effects of Grinding on Physical Properties of Hardened Steel Parts," Paper No. 23) the effects of grinding stresses are correlated with structural changes occurring in a high carbon, low alloy steel.

Several important observations were made: (1) Even the most careful grinding induces tension stresses in the ground surfaces and thus disturbs the stress balance. (2) Austenitizing temperature has a marked influence on the stress condition induced by grinding. (3) The shock resistance is decreased by grinding. (4) The fatigue resistance is also lowered.

The author points out that some of these effects can be minimized by proper planning of grinding operations. For example, often the parts can be ground in the soft stage. This, of course, requires proper heat treatment to produce clean and distortion-free parts.

Chromium-Silicon Spring Steel

For the spring engineer, H. J. Elmendorf of American Steel & Wire Co. in his paper ("An Investigation of Tempered Chromium-Silicon Spring Steel," Paper No. 1) outlined the effects of heat treating practices on the mechanical properties of chromium-silicon steel under both room and elevated temperature conditions. The analysis of this chromium-silicon steel is 0.50 to 0.60 carbon, 0.60 to 0.80 manganese, 1.30 to 1.60 silicon, and 0.50 to 0.80% chromium.

The tension stress-strain curves for stress relieved, "blued," chromium-silicon spring wires show marked changes in shape as a function of the bluing temperature, and these changes are associated with the hardness of the tempered wire. This change in the stress-strain relationship is reflected in the mechanical properties of the blued spring wires.

The elastic limits of 48.5 and 50 Rockwell C wires blued at 500, 600, and 700 F are higher than the values for the similarly blued 52.5 Rockwell C. Elevated temperature spring tests show that 50 Rockwell C wire has optimum properties. It was also observed that the chromium-silicon steel is superior to SAE 6150 under the conditions studied.

Cast Steel

Three papers of interest were presented on cast steel. The effect of silicon on thermal characteristics, microstructures, physical properties and weldability of plain carbon and carbon-molybdenum cast steels of three carbon contents (0.1 max., 0.15 and 0.30% carbon) was investigated by N. A. Ziegler, W. L. Meinhart and J. R. Goldsmith of the Crane Co. ("The Effect of Silicon on the Properties of Cast Carbon and Carbon-Molybdenum Steels," Paper No. 29). The silicon content was increased from 0.3 to 2% and the results observed. Additions of 0.3 to 2% silicon tends to raise transformations on cooling to higher temperatures. Thus, the general trend is a decrease of thermal sluggishness with increasing silicon.

Effects of increasing silicon from 0.3 to 2% on the mechanical properties are: (1) moderate increase of tensile strength, yield point and hardness, (2) very moderate decrease of elongation and reduction of area, and (3) considerable reduction of impact resistance. Metal arc welding of steels with the silicon content as high as 2% did not present any particular difficulties.

The effects of homogenization heat treatments on hardenability, impact properties and time-temperature-transformation curves for certain cast steels were reported by R. J. Marcotle and C. T. Eddy of Michigan College of Mining & Technology ("The Effect of Homogenization on Cast Steels," Paper No. 30). Investigations were made principally on cast steel of low hardenability and one of high hardenability.

The investigation showed that homogenization heat treatments using high heat treating temperatures or normal heat treating temperatures for long heating times, are not sufficiently effective in improving the mechanical properties of cast steels to be employed.

And finally, Edward A. Loria of the Mellon Institute of Industrial Research, gave an account of a method of measuring the as-cast austenite grain size in cast alloy steels ("Detection of As-Cast Austenite Grain Size in Heat Treated Cast Alloy Steels," Paper No. 28). The effect of grain size is of great importance to the foundryman, especially just after the steel is cast and again after any reheating operation carried out above the critical temperature range.

In this new method the grain size is measured by considering the effects of solidification pattern and segregation of alloying elements on the development of the as-cast grain pattern. In rapidly cooled sections the marked segregation results in increased local hardenability and the development of an outline of the initial austenite grain boundaries upon etching with modified picral reagent. In the manganese-molybdenum cast steels studied, normalizing or quenching and tempering followed by etching with a modified picral solution gives the necessary split transformation in the alloy-rich and alloy-poor localities and a microstructural delineation of the intercell network existing in such steels.

Vacuum and Prepared-Gas Atmosphere Heat Treating

Condensed from a Report of the American Gas Association

An investigation was conducted by the American Gas Association to determine what, if any effects, either advantageous or otherwise, were produced by gas absorption during the usual operations to which steel is subjected in heat treatment. A series of heat treating experiments were conducted in a controlled vacuum furnace.

In general it was found that small quantities of absorbed gases do have deleterious effects upon the properties of the metal, but such effects are rather small. Comparatively coarse measurements such as hardness and tensile strength are for the most part unaffected, whereas processes or measurements such as malleableizing or fatigue life, which are affected by small changes, do exhibit recognizable differences. For these reasons, absorbed gases can probably best be thought of as inadvertent minor alloying additions. When these additions are allowed to become large through pickling or faulty melting practice, as examples, pronounced effects can result. When the gases are present in amounts corresponding to their solubility values, which are small, their effects are correspondingly small.

It has been found that vacuum malleableizing is superior in consistency, physical properties, and speed to any of the common prepared atmospheres. The improvement over low hydrogen atmospheres is not very pronounced, however. These tests have definitely shown that hydrogen interferes with the malleableizing process, making the use of high hydrogen atmospheres inadvisable for the process. It has been found that in one case evacuation prior to quenching prevented the samples from cracking, whereas the same steel did crack when quenched from RX gas. Definite improvement in the fatigue life of beryllium-copper valve springs was developed by carrying out the age hardening treatment in vacuum rather than in air.

It has been demonstrated that steel is as easily carburized by a hydrocarbon gas in the absence of oxygen compounds as it is when such compounds are present. In fact, the carburizing potential was slightly

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higher than would be expected. It was also shown that the carbon diffusion rate was identical in vacuum, in nitrogen, and in the conventional hydrogen containing carburizing atmospheres. In demonstrating this fact, a valuable equation was devised to predict the carbon gradient after any diffusion treatment.

Spheroidizing tests have shown that the spheroidizing rate is not influenced by vacuum. The deep drawing properties of rimmed and killed steels were not improved by vacuum annealing. Quenching steel from vacuum failed to improve either the impact strength developed or the fatigue life. (Jack Huebler. Report of *Am. Gas Assoc.*, 19 pp.)

Progress in Castings for Machine Tools

Condensed from "Machines et Métaux"

There has been considerable progress in quality cast iron in the past few years, particularly in machine tool castings subject to abrasion. Until about ten years ago, these were generally made with a charge of about 25 to 50% steel and contained high carbon and low silicon. This material was relatively unsatisfactory because it was impossible to obtain a desirable structure in castings having varying sections. The use of nickel made it possible to control these variations. In this period, however, little attention was paid to the carbon content, while the silicon was adjusted according to the section.

The desire to avoid these frequent changes and the demand for more uniform castings which would give a better surface finish and a greater wear resistance led to the adoption of high strength irons, made with a low carbon content, a relatively high silicon content, and about 70 to 95% steel in the charge. This iron was ideal with one exception, the scratching of the wearing or sliding surfaces.

Work by Dost in the U.S.A. has shown that microstructure is a more decisive factor in this connection than hardness or chemical composition. The scratching is definitely attributable to the presence of primary ferrite. Flake graphite gives better wear resistance than nodular graphite. Some castings with fine nodular graphite have relatively poor wear resistance even when ferrite is absent. Nickel helps in maintaining a normal hardness in thin sections and a dense structure in heavy sections. The fine pearlitic structure of the nickel iron

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results in good wear resistance and low susceptibility to scratching.

The automobile industry offers sufficient proof that moderately hard cast irons have the best wear resistance. If higher hardnesses are necessary for still better wear resistance, the hardness of these medium carbon, low silicon irons can be increased by additions of nickel suitably balanced with chromium or molybdenum. In these cases, the graphite flakes may be somewhat coarser and the pearlite may be replaced by the harder sorbite. Although service conditions are quite different in internal combustion engines than in machine tools, here too the presence of primary ferrite has been found undesirable for surfaces exposed to wear.

The final conclusion is that it is dangerous to rely solely on hardness to predict the wear resistance of cast iron. (G. Martel. *Machines et Métaux,* Vol. 31, Aug. 1947, pp. 269-273.)

Pre-Tinning as a Base for Paint

Condensed from "Tin and Its Uses"

Another coat of paint is not a complete answer to the rusting of iron base materials. If the surface of the steel rusts underneath the paint, a scraping and cleaning operation is required for proper adhesion of the new coat of paint. Even the best paint, if put directly on steel, is far from a permanent basis for resisting rusting.

The new process of putting an extremely thin coating of tin on steel before painting appears to provide the most nearly perfect coating so far devised. Tests with various steels, paints and pre-treatments have been conducted for some four years. In every case, those steel specimens which had been pre-tinned have retained their paint longest and, what is perhaps more important, they have retained a repaintable surface. Although zinc gives protection when left unpainted, any zinc coating is unsatisfactory under paint because a rather bulky corrosion product is formed below the paint, which destroys the paint coating.

The idea of a thin tin coating as a protection against rust is somewhat novel since ordinary tinplate rusts rather freely. The important fact is that the superimposition of paint entirely alters the corrosive conditions. Tin has two outstanding qualities. It is inherently corrosion resistant, and its natural oxide film is so thin that tin will remain bright for long periods. In addition,

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it has a peculiar affinity for oils and lacquers. These two qualities can be utilized to provide a permanent basis for paint even though the tin film is only 0.00005 to 0.00003-in. thick.

The use of pre-tinned sheet furnishes an exceptionally smooth surface of high reflectance requiring fewer coats of paint for a finish of equal quality. The use of tinned steel, therefore, not only gives much longer service life but also effects a substantial reduction in first costs. (*Tin and Its Uses*, No. 18, July 1947, pp. 5-7, 11.)

Impact Properties of Semi-Hard Electric Steel

Condensed from "Revue de Métallurgie"

Electric furnace, 0.2% carbon steel castings are ordinarily melted in France in a basic furnace, but an acid furnace has also been used. Although the only difference in melting practice is the addition of less aluminum in the ladle for the acid steel, the latter steels consistently show lower impact than the former.

Regardless of the type of melting, aluminum additions up to 0.15% were found to exert a deleterious effect on the impact of the steel as cast. The extent of the decrease in impact, however, was not constant for all heats, as it seemed to be aggravated by the influence of other factors. In all cases, a homogenization anneal appreciably increased the impact, and overcame the deleterious effect of the aluminum. The recovery of impact by annealing seemed to be complete for basic steels, but was only partial in the case of acid steel containing about 0.6 manganese, 0.035 sulfur and 0.035% phosphorus.

It was possible to obtain acid steel with impact properties in the annealed condition very close to those resulting from basic melting, if the manganese was increased to a minimum of 0.7%, if the sulfur content was lowered, and if the smallest possible aluminum addition was used. With this higher manganese content, the carbon content for a specific tensile strength can be lowered.

Longitudinal impact tests on forged and annealed steel from the same heats indicated that the effect of the aluminum was the reverse of that found with the cast steel. As a general rule, the impact increased with the amount of the aluminum addition.

In view of the work of Sims, Dahle and

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Lilliequist, the effect of aluminum on the size and distribution of the sulfur inclusions was investigated. In the as-cast steel, there was a tendency for the aluminum to cause the sulfur to form grain boundary inclusions. The favorable effect of annealing and hot working on the impact properties is attributed to a fragmentation of these inclusions. (P. Bastien & C. Dubois. *Rev. Métallurgie,* Vol. 43, Nov.-Dec. 1946, pp. 297-306.)

Welding Aluminum-Magnesium Alloys

Condensed from "Sheet Metal Industries"

In the development of high strength, weldable, aluminum base alloys, it is essential that the cast material have properties near those of the wrought material, that the properties of the latter not be seriously affected by the welding heat, and that the casting properties be good. The aluminum-magnesium alloys largely meet these requirements. In making sound welds, the main difficulties are: (1) a marked tendency to develop porosity and blistering in and adjacent to the weld bead, and (2) a tendency to crack when welded under restraint.

Blistering is caused by the absorption of hydrogen during fabrication. Aluminum-magnesium sheet with a minimum tendency to blister can be produced if the following recommendations are observed: (1) thorough degassing of the molten metal, preferably with chlorine; (2) no use of flux for degassing and melting which introduces calcium or other reactive elements into the metal since these impurities favor the reaction with water vapor; (3) sound ingots; (4) avoidance of gas pick-up during heat treatment by keeping the sheet dry and by annealing in atmospheres as free as possible from water vapor and preferably containing traces of hydrofluoric acid to inhibit the reaction. In welding, the surface of the sheet must be cleaned mechanically immediately before welding, and the welding time should be as short as practicable.

Although less blistering is found in low magnesium alloys, their mechanical properties are not as good and they tend to crack when welded under constraint. There are advantages in using a filler rod of higher magnesium content than the basis metal, particularly when the magnesium content of the latter is under 7%.

Material has been produced under laboratory conditions which is free from blistering. Such material has also been produced in

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Germany. It appears that the Germans were not fully aware of the precautions necessary to produce welding quality sheet and that only a part of their output, selected by empirical welding tests, was considered suitable for welding.

Manufacturers in Britain are working on the problem of producing welding quality sheet, but the necessary precautions to produce such material are difficult to comply with in industrial practice. Further work is required to make them more practicable. (E. A. G. Liddiard, *Sheet Metal Inds.*, Vol. 24, Sept. 1947, pp. 1857-1860, 1862.)

New High Strength Aluminum-Magnesium-Zinc Alloys

Condensed from "Revue de l'Aluminium"

Very much in the forefront of the light alloy field are the high strength aluminum-magnesium-zinc alloys. A detailed discussion is given of the development and properties of Zicral, an aluminum alloy which contains 7 to 8.5 zinc, 2.5 magnesium, 1.5 copper and 0.25% chromium.

The solution temperature is 870 F ± 25 F. Less precise temperature control is needed than with duraluminum. For optimum properties, the interval before quenching should be under 15 sec. Oil or water quenching can be used. In contrast to duraluminum, room temperature aging is not satisfactory. To eliminate the risk of intergranular corrosion, Zicral should be aged at least 5 hr. at 275 F or higher. Cladding with either a 4% zinc or a 1% zinc alloy gives added corrosion resistance even when the cladding is discontinuous. Anodizing in sulfuric acid produces excellent surface protection.

Unquestionably, the use of this alloy, which will develop a yield point of 64,000 to 71,100 psi. in rolled products and 78,200 to 85,300 psi. in drawn wire, will lead to a notable weight saving in parts constructed of aluminum, especially in airplanes. These characteristics are appreciably higher than those of the aluminum-copper-magnesium alloys, which have a yield point of only 45,500 to 54,000 psi. Moreover, the fatigue limit of Zicral is about 24,200 psi., whereas no other light alloy is much over 19,900 psi.

In comparison with these advantages, the disadvantages are minor. The new alloy requires a little more care in hot rolling

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than most of the other light alloys, and it has a lower plastic deformation before rupture. Design engineers must consequently modify their opinions and particularly must study new and modified methods of assembly. (P. Vachet. *Rev. l'Aluminium,* Vol. 24, June 1947, pp. 189-198; July/Aug., pp. 225-233.)

Aluminum Foil Production in Germany

Condensed from "Metal Industry"

A description is given of the rolling of aluminum foil and strip at Rheinische Blattmetal, Germany. Slabs were cut from ingots and machined all over. After being heated at 840 to 895 F, the slabs were hot rolled in 6 to 12 passes in two-high reversible mills to strip 0.24 to 0.28-in. thick. Without annealing, the strip was cold rolled to 0.03 to 0.04 in. in 8 to 12 passes. The coiled strip was edge trimmed and annealed at 895 to 930 F. The strip was then passed to a series of foil rolling mills, in which the width of the foil remained constant as the foil passed through. Normally the foil was given only one reduction in each mill. Mineral oil was dripped onto the roll during rolling.

After the last reduction pass, the foil was passed without reduction through a set of rolls flooded with gasoline. For the standard 0.00035-in. foil, six reduction passes were required with only a final anneal. For 0.00026-in. strip for electrolytic condensers, seven passes were used. Experimentally, 0.00010-in. foil had been produced by rolling four thicknesses together.

The thickness during rolling was checked with a micrometer and, in the final inspection, by a special electrical gage. Finished foil was also checked for thickness by determining the weight of a specific length of foil of known width. Electrolytic condenser foil was examined visually for pinholes.

High purity metal (99.99%) was difficult to roll as it tended to work harden at the center of the strip but remained soft at the sides. The normal grade (99.3 to 99.5%) was much more amenable, but if the metal was rolled too fast it work hardened and could not be rolled satisfactorily. Pinholes were due mainly to casting defects, which showed up in the early stages, or to dust falling on the foil during rolling, which sometimes did not become evident until the final pass. (*Metal Ind.,* Vol. 71, Aug. 22, 1947, p. 153; as abstracted from a recent B.I.O.S. Report, number not given.)

BOOK REVIEWS

The Government's "Ship Failures" Report

THE DESIGN AND METHODS OF CONSTRUCTION OF WELDED STEEL MERCHANT VESSELS — REPORT OF AN INVESTIGATION. *Published by Government Printing Office, Washington, D. C., 1947. Fabrikoid, 8 x 10½ in., 164 pages. Not available for public sale or distribution.* In the final report of the Board convened by the Secretary of the Navy to investigate the design and methods of construction of welded steel merchant vessels (made after the investigation had been in progress for more than three years), the following conclusions were reached:

(a) The fractures in welded ships were caused by notches and by steel which was notch sensitive at operating temperatures. When an adverse combination of these occurs the ship may be unable to resist the bending moments of normal service.

(b) The serious epidemic of fractures in the steel structure of welded merchant vessels has been curbed through the combined effect of the corrective measures taken on the structure of the ships during construction and after completion, improvements in new design, and improved construction practices in the shipyards.

(c) Locked-in stresses do not contribute materially to the failure of welded ships, etc., etc.

In the opinion of the Board, the results of the investigation have vindicated the all-welded ship. The statistics show that the percentage of vessels sustaining serious fractures is small. With proper detail design, high quality workmanship, and a steel which has low notch sensitivity at operating temperatures, a satisfactory all-welded ship structure may be obtained. The Board also reaffirmed the statement that if welded construction in the building of both merchant and naval vessels had not been adopted at the outset of the program, the extraordinary results in speed and volume of construction would have been impossible of accomplishment.

The report was divided into five parts: Structural Failure History; Analysis of Factors Contributing to Structural Failures; Susceptibility to Fracture of Different Ship Designs and Structural Details; Effectiveness of Certain Structural Alterations; and Steel Quality. Exhibits appended

to the report cover: Statistical Analysis of Structural Failures on Welded Steel Merchant Vessels; Summary of Research Investigations; and Survey of Shipyard Welding Practices.

Other New Books

HOLDING LOW TEMPERATURES WITH BETTER INSULATION. *Published by Industrial Mineral Wool Institute, New York, 1947. 8½ x 11 in., 24 pages.* Contains information on how to select insulation and what to look out for; data on forms, properties and application methods; and principles and significance of vapor-proofing for various types of wall, floor and ceiling construction.

MANUAL OF ALUMINUM CASTING ALLOYS. *Published by Aluminum Research Institute, Chicago, 1947. Fabrikoid, 6 x 8¾ in., 78 pages. Free to applicants on company letterheads.* Contains factual data on the qualities of aluminum casting alloys, the results of a program of research carried on by the Metals Research Laboratory of Case Institute of Technology.

CONCISE CHEMICAL AND TECHNICAL DICTIONARY. *Edited by H. Bennett. Published by Chemical Publishing Co., Inc. Brooklyn, N. Y., 1947. Cloth, 6¼ x 9¼ in., 1095 pages. Price $10.00.* Includes about 50,000 definitions covering all fields of scientific and technical development. A compilation of trade-name or proprietary products in the synthetic resin, plastic, metal, rubber, textile, food, pharmaceutical, paint and varnish fields is a special feature.

COMPRESSED AIR HANDBOOK. *Published by Compressed Air & Gas Institute, New York, 1947. Fabrikoid, 6 x 9 in., 400 pages. Price $3.00 in U.S.A.; elsewhere $3.50.* Reference text on applications, installation, operation and maintenance of compressing equipment and air-powered tools of all types. The material formerly published as "Trade Standards" is included in revised form.

EXPERIMENTAL STRESS ANALYSIS, VOL. IV, No. 2. *Edited by C. Lipson & W. M. Murray. Published by Addison-Wesley Press, Inc., Cambridge, Mass., 1947. Cloth, 8½ x 11¼ in., 121 pages. Price $6.00.* Twelve papers or discussions are contained in this volume of the Proceedings of the Society for Experimental Stress Analysis. The subjects include: Fatigue Tests of Major Aircraft Structural Components, Precision Determination of Stress-Strain Curves in the Plastic Range, A Method of Detecting Incipient Fatigue Failure, A Machine for Fatigue Testing Full-Size Parts, Some Repeated Load Investigations on Aircraft Components, and Aircraft Instruments for Radio-Telemetering and Television-Telemetering.

UNITED STATES PATENTS ON POWDER METALLURGY. *By R. E. Jager & R. E. Pollard. Published by United States Government Printing Office, Washington 25, D. C., 1947. Paper, 6 x 9 in., 139 pages. Price 30c.* More than a century of progress is represented by these patents, which have been classified as to production, handling and working, alloying, and application with a short abstract for each item.

A CENTURY OF SILVER — *1847-1947. By Earl C. May. Published by Robert M. McBride & Co., New York, 1947. Cloth, 6¾ x 9¼ in., 388 pages. Price $3.50. Illustrated.* Tells the story of silverware from the days of the early Yankee silversmiths making plated products by crude methods, through the making of britannia ware, which marked the beginning of mass production, up to the plated and sterling ware of the present time.

MANUFACTURERS' LITERATURE

Materials

Iron and Steel

Chromium-Nickel Steel. Typical applications, physical and mechanical properties, and the forging, annealing, hardening, forming, machining, welding, etc., of Rezistal 302, a non-hardenable austenitic chromium-nickel steel, are all included in this 4-page data sheet, No. 302, published by the Crucible Steel Co. of America. (1)

Corrosion Resisting Alloys. A guide to the selection of Durco corrosion resisting alloys in the form of tables listing the characteristics of Durco alloys and the resistance of Durco alloys to corrosive solutions is offered by the Duriron Co., Inc., in a 4-page bulletin, No. 100. (2)

Nonferrous Metals

Carbide Metal. Prices and specifications of 1325 different sizes of blanks, bars, strips, rods, tubes, bushings, rings, flats, tips, disks and shapes made of Talide Metal, a solid tungsten carbide metal for wear-resistant applications, are listed in an 8-page bulletin, No. 47-WM, offered by the Metal Carbides Corp. (3)

Laminated Metals. This 4-page, illustrated bulletin offered by the General Plate Div. of Metals & Controls Corp. discusses laminated metals and laminated silver contacts that are available in flat stock, tubing and wire form in various sizes and thicknesses. Typical applications are included. (4)

Metal Powders. Six types of metal powders and their many applications in the powder metallurgy, electronics, chemistry, welding rods and other fields are discussed in a single-page bulletin issued by the Plastics Metals Div. of the National Radiator Co. (5)

Metal Powders. Complete data on a variety of zinc, brass, bronze and copper powders for use in brazing, metal spraying, powder compacting, and chemical processes are presented by the New Jersey Zinc Co. in a 4-page, illustrated bulletin. (6)

Nickel and Nickel Alloy Tubing. Complete data on nickel and nickel alloy small tubing—0.010- to ⅝-in. max. O.D.—in both seamless and Weldrawn (welded and drawn) form are presented by the Superior Tube Co. in a 16-page, illustrated bulletin, No. 10. (7)

Parts and Forms

Aluminum and Magnesium Sand Castings. The facilities of the Acme Aluminum Foundry Co. for producing high quality sand castings of aluminum and magnesium alloys, as well as tabular data on typical applications, chemical compositions and mechanical properties, are described and illustrated in a 16-page bulletin. (8)

Aluminum Castings. A variety of high quality sand and permanent mold aluminum castings produced by the Advance Aluminum Castings Corp. are profusely illustrated and described in a 4-page bulletin. (9)

Stainless and Heat Resisting Castings. A complete range of Accoloy stainless steel and heat resisting castings for producing baskets, trays, fans, fixtures, pots, boxes, etc., for carburizing, annealing and nitriding furnaces are listed in a 4-page, illustrated bulletin offered by the Alloy Casting Co. (10)

Special Shaped Wire. Tabular data on the physical properties of steel wire, standard wire gages, hardness conversion, carbon and alloy steel weights, etc., are included in this 16-page, illustrated bulletin, No. 01A, covering special shaped wire in rounds, squares, triangles, keystones, half-rounds, full oval and flats, produced by the Page Steel & Wire Div. of American Chain & Cable Co., Inc. (11)

Precision Investment Castings. Excerpts from an article on precision investment castings are compiled into a 12-page, illustrated booklet published by the Arwood Precision Casting Corp. (12)

Cast Ferrous Metal. The properties, advantages, fields of application and required engineering data of ArmaSteel, a cast ferrous metal that combines the simplicity and adaptability of castings with the strength and reliability associated with forgings, are discussed in a 38-page, illustrated catalog offered by the Central Foundry Div. of General Motors Corp. (13)

Castings. The most recent developments in the engineering applications of Meehanite castings are compiled into an 8-page, illustrated bulletin, No. 25, just published by the Meehanite Metal Corp. (14)

Metal Fabrication. The facilities of the Metal Fabricating Div. of the W. S. Rockwell Co. for producing any kind of fabricated parts, sub-assemblies, complete assemblies, and special machines for use in a variety of industries are described in a 4-page, illustrated bulletin, No. 427. (15)

Powder Metallurgy. The establishment of the Sintercast Corp. of America with facilities for basic research and industrial development in the field of powder metallurgy is announced in a 12-page, pocket-size folder. (16)

Plastics

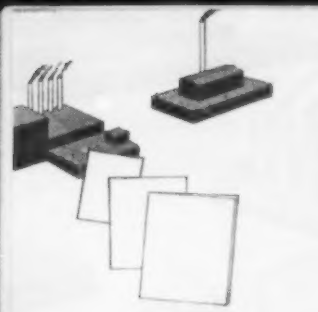
Fiberglas in Machine Tool Motors. Complete data on the use of Fiberglas electrical insulation materials in machine tool motors to reduce bulk and weight and provide improved performance are presented by the Owens-Corning Fiberglas Corp. in a 12-page, illustrated bulletin. (17)

Methods and Equipment

Heat Treating

Heat Treating Furnace. The many advantages of using an automatic batch-loading, continuous-unloading, bright-hardening furnace mounted directly on an automatic-unloading quench tank for efficient heat treating are discussed by Ipsen Industries, Inc., in a 4-page, illustrated bulletin. (18)

Induction Heating Equipment. This 6-page, illustrated folder published by Lepel High



MANUFACTURERS' LITERATURE

Frequency Laboratories, Inc., discusses high frequency induction heating units for hardening, annealing, stress relieving, soldering, brazing and melting operations. (19)

Hardening Stainless Steel. This 16-page, illustrated booklet discusses the Super Scottsonizing method of processing stainless steel, which gives steel a 5/1000th case on a finished part without warpage, and holds the parts to 2/10,000ths tolerance and yet retains the stainless qualities of the steel. C. U. Scott & Son, Inc. (20)

Heat Treating Methods and Equipment. This 32-page, illustrated catalog discusses the broad activities in metallurgical research of the Surface Combustion Corp., and the designing and manufacturing of heating equipment for the metal-producing and working industries. (21)

Resistance Welding Electrodes, Tips, Holders, Alloys. Specifications and prices of a complete line of resistance welding electrodes, replaceable tips, water-cooled holders, seam welding wheels, special dies, and refractory alloys are included in this 24-page, illustrated catalog, W-102, just released by Weiger Weed & Co., division of the Fansteel Metallurgical Corp. (22)

High Temperature Electric Furnaces. Three types of Wesgo high temperature electric furnaces for ignitions, hardening, annealing, enameling, etc., are described and illustrated in a 6-page, pocket-size folder offered by the Western Gold & Platinum Works. (23)

Welding and Joining

Tungsten Carbide Brazing. The equipment and materials required, as well as instructions on how to braze tungsten carbide tool tips or wear parts by torch, furnace or induction, are described and illustrated in a 12-page, pocket-size booklet offered by the Adamas Carbide Corp. (24)

Fuel Gas for Welding and Cutting. Complete data on Airco Acetylene as a fuel gas for oxyflame welding and cutting are presented by the Air Reduction Sales Co. in a 12-page, illustrated booklet, ADG-1050. (25)

Hard Overlay Welding. This 8-page, illustrated bulletin, No. 9, discusses specific procedures involved in industrial equipment salvage welding with various gas and arc rods for producing hard overlay at low temperature, using a variety of eutectic alloys produced by the Eutectic Welding Alloys Corp. (26)

Silver Brazing Alloys. The many applications of two types of silver brazing alloys—Sil-Fos and Easy-Flo—during the last war and now in peace time are discussed in a 4-page illustrated bulletin, No. 33, published by Handy & Harman. (27)

Multi-Range Arc Welder. How to increase production speed on both light and heavy duty welding through the use of a multi-range arc welder with dual control and remote control is discussed by the Hobart Brothers Co. in their 4-page, illustrated bulletin, No. 8731. (28)

Arc Welding Accessories. A complete line of arc welding accessories, such as cable connectors and splicers, hammers, protective clothing, cleaning tools, etc., that will be carried in stock at each of the district offices of the Metal & Thermit Corp. is described and illustrated in a 16-page bulletin, No. 120. (29)

Bronze Welding Rods. The approximate chemical and physical properties of seven types of doubly deoxidized bronze welding rods are included in this 6-page, illustrated folder issued by the Titan Metal Manufacturing Co. (30)

Electric Arc Welder. This 2-page bulletin describes and illustrates the new, portable three-in-one electric arc welder that welds, brazes and solders all metals, produced by the Tri-Arc Corp. Price is included. (31)

Forging and Forming

Drawing and Embossing Sheet Metal. The Hydrodynamic process of drawing and embossing sheet metal especially adapted for forming shallow sweeps and shapes and drawing cone shaped and tapered stampings is discussed in a 12-page, illustrated bulletin issued by L. V. Whistler & S. A. Whistler. (32)

Machining

Grinding Carbide Milling Cutters. This 16-page, illustrated booklet, No. M-1608, interestingly presents a group of recommendations for grinding carbide milling cutters, as suggested by the Cincinnati Milling Machine Co. (33)

Single Spindle Automatic Machine. The new Model AB Dialmatic, a 2½-in. single automatic machine with electric tool drive, is described by the Cleveland Automatic Machine Co. in their 6-page, illustrated folder. Complete specifications are included. (34)

Shapers. How various splines, cams, sprockets, gears, clutches, ratchets and miscellaneous external shapes can be rapidly produced on four available models of Shear-Speed shapers is explained in detail by the Michigan Tool Co. in their 8-page, illustrated bulletin, No. 1800-47. Specifications are included. (35)

Lubricants and Coolants. Complete data on a variety of cutting and soluble oils, cutting operations, functions of cutting fluids, etc., are presented in detail in a 46-page, illustrated booklet published by the Texas Co. (36)

Cleaning and Finishing

Melting and Dispensing Tanks. Two new indirectly heated, thermostatically controlled melting and dispensing tanks with indirectly heated dispensing valves are discussed in a 2-page, illustrated bulletin, No. 603, issued by Aeroil Products Co., Inc. Complete specifications are included. (37)

Abrasive Grains. A complete line of Carbolon and Exolon abrasives, their list prices per lb., and general recommendations for surface finishing are listed in a 6-page, illustrated folder issued by the Exolon Co. (38)

Emulsifying Agents. A variety of non-ionic emulsifying agents that are not affected by hard water, salts, dilute acids, etc., are discussed in four data sheets published by the Glyco Products Co., Inc. (39)

Protective Coating. Physical, general and chemical properties, specifications and application of Ryno-Hyde 9, a strippable protective coating that is applied to metal surfaces by spray equipment, are all included in a 4-page folder, No. 11, published by the R. M. Hollingshead Corp. (40)

Corrosion Resistant Lining and Coating. A solution to metal losses from severe wear and corrosion, particularly in extruding cylinders, tubes and strainers, through the use of both Xaloy and Xaloy 306—as an internal, homogeneously-bonded lining to steel cylinders and as an external coating to steel tubes—is offered by the Industrial Research Laboratories, Ltd., in a 12-page, illustrated bulletin. (41)

Portable Vapor Degreasers. The many advantages of using either electric or steam portable vapor degreasers for removing oil, grease, resins, dirt, etc., from all metals are presented in a 4-page, illustrated bulletin issued by Midwestern Sales, Inc. (42)

Polishing and Buffing Machines. A complete line of new, improved Packer-Matic automatic machines for polishing, buffing, deburring and grinding operations are described and illustrated in a 4-page bulletin, No. 16, offered by the Packer Machine Co. (43)

Belt Grinder-Polisher. A new method of contoured and straight-faced grinding through the use of a Type C-6 dry belt contact wheel grinder produced by the Porter-Cable Machine Co. is discussed in an 8-page, illustrated bulletin, No. 660. Complete specifications are included. (44)

Inspection and Control

Determining the Modulus of Elasticity. Tests made with the Aminco Modulimeter for determining the stiffness and modulus of elasticity of plastics, rubber, metals, lami-

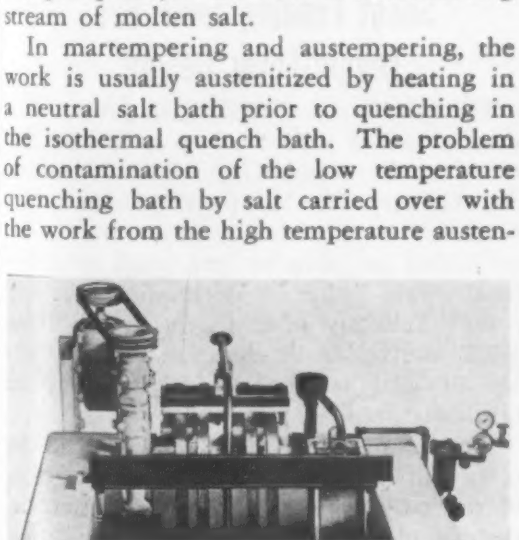
New Materials and Equipment

Salt Bath Furnace for Interrupted Quenching

A new design electric salt bath furnace for use with the isothermal heat treat process is being offered by the *Ajax Electric Co.*, Philadelphia 23. This process involves interrupted quenching such as is used in martempering, austempering and cyclic annealing. The quench furnace employs the principles of a heat exchanger to hold the quenching bath at a constant temperature. Since the work transfers a great amount of heat to it, the bath must be capable of absorbing and dissipating this heat to avoid temperature build-up.

In order to provide the maximum cooling power, the isothermal quench furnace is provided with a motor operated, high capacity, submerged pump; the outlets of this pump subject the work to a fast moving stream of molten salt.

In martempering and austempering, the work is usually austenitized by heating in a neutral salt bath prior to quenching in the isothermal quench bath. The problem of contamination of the low temperature quenching bath by salt carried over with the work from the high temperature austenitizing bath is eliminated by a recently developed salt separator which is immersed directly in the isothermal quench bath.



The salt bath furnace features a high capacity submerged pump and a salt separator.

The isothermal quench furnace can be heated either by immersed electrodes for high temperature work, or by immersion heating elements for low temperature work.

New Welding Rods and Fluxes

An improved all position, mild steel electrode, No. 512, has been announced by *Wilson Welders & Metals Co., Inc.*, 60 East 42nd St., New York 17. This electrode has two advantages over its predecessor in that it can now be used on a.c. and d.c. reverse polarity current with the operating characteristics being equal. Secondly, preheating of this electrode is no longer required to obtain porosity-free weld deposits that are obtainable by using either the stringer bead or the full weave technique.

Recommended applications for the electrode are: welding high sulfur, free machining steels; welding hardenable steels where no preheat is used; welding cold rolled steels which normally exhibit excessive porosity when welded with conventional electrodes; weldments to be vitreous enameled after welding.

A new silicon bronze arc welding electrode, "Sil-Trode", has been developed by *Ampco Metal, Inc.*, Milwaukee 4, Wis., for those who prefer to use an electrode of similar composition to the parent metal when fabricating and repairing silicon bronze parts. It is a shielded-arc silicon bronze electrode operating on reverse (positive) polarity, direct current. The coating and core wire were specifically designed to produce a spray type arc action, low spatter loss, free-flowing slag, and weld metal producing crack-free, smooth, dense deposits. The rod is primarily recommended for the metallic-arc welding of silicon bronzes, although like most other bronze electrodes, it may be used to weld copper, dissimilar metals and ferrous base metals.

A pure nickel electrode, Eureka No. 100, for welding all types of cast iron has been announced by *Welding Equipment & Supply Co.*, 223 Leib St., Detroit 7. The rod is suited for repairing cast-structured drawing and forming dies, and is generally used as an intermediary material between the base metal and the final deposition. The electrode operates on either d.c. or a.c. welding currents, and is said to produce a stable, smooth and spatter-free arc action with perfect slag coverage of weld deposits.

All-State Welding Alloys Co., Inc., 96 West Post Road, White Plains, N. Y., announces the availability of a new flux for joining aluminum with dissimilar ferrous and nonferrous metals at low working temperatures. Where this flux is used with aluminum solder, the joint has the advantage of being considerably stronger than a similar one made without the flux. This flux is known as All-State No. 39 Flux.

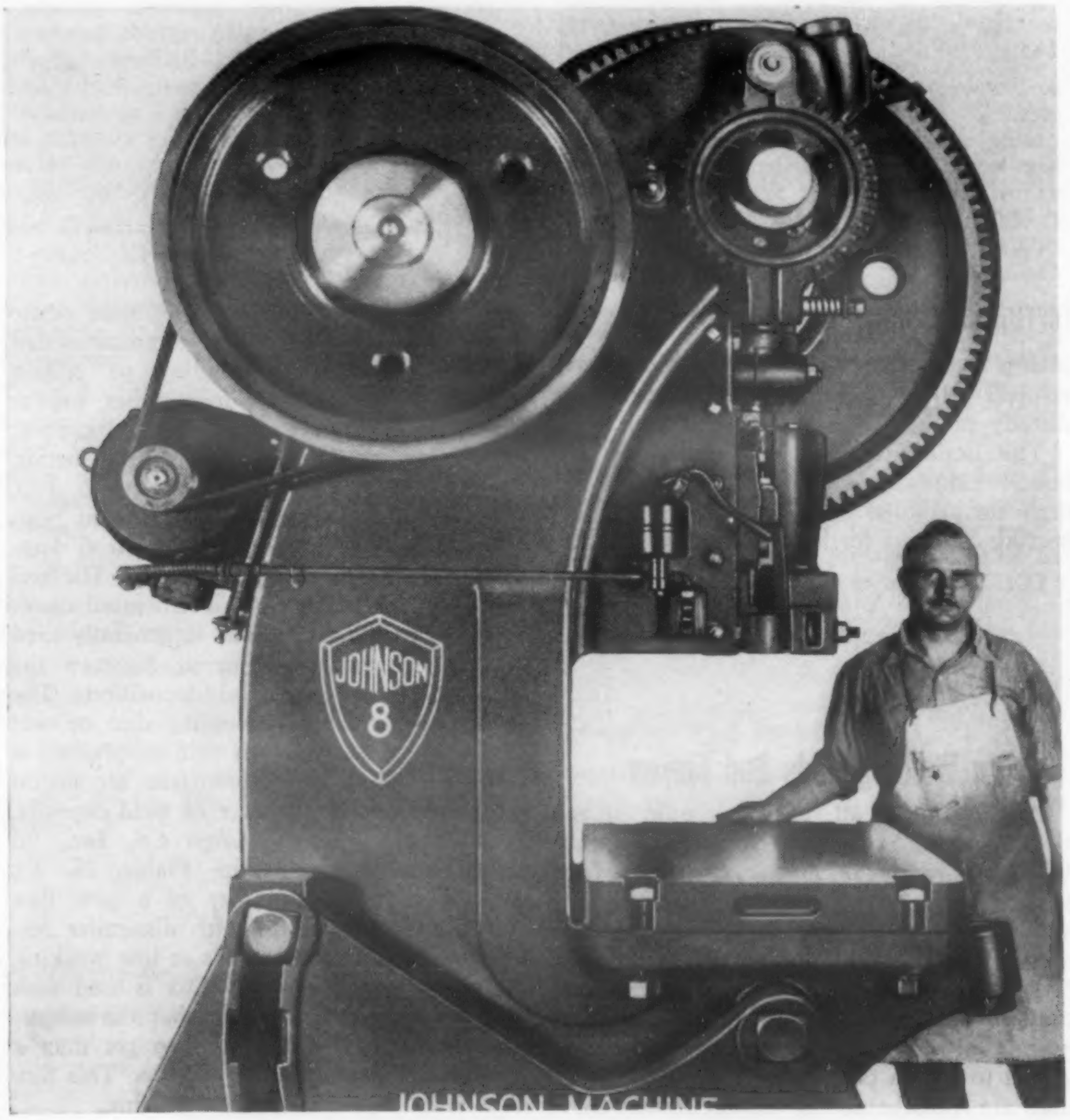
● A vise of solid bronze with tool steel fingers has been designed and is being produced by *Benjamin Alydess & Sons, Inc.*, 962 E. 167 St., New York. The ground jaws on the vise can hold from 0.001-in. in thickness to 2½ in. at any point within the jaws. A feature is the use of tool steel fingers held in receptacles within the upper and lower jaws. There are six receptacles placed in the front of the jaws so that by shifting these fingers within the various receptacles, the mechanic can accommodate many odd shapes and sizes, *i.e.*, disks, gears, balls, half balls, medallion hobs, etc.

Inclinable Power Press Has 90-Ton Capacity

A new inclinable power press of 90-ton capacity is being produced by the *Johnson Machine & Press Corp.*, Elkhart, Ind. It can be used in the horizontal position or tilted back at a 25° angle so that the work will drop away from the press without the use of an ejector. The new press can handle work up to 15 in. in depth, and produces 44 pieces per min.

It has an extra thick bolster plate which provides extra strength for heavy operations without reducing die space. An interchangeable thin steel bolster is available to give greater than normal die space for a press of this size, without sacrificing strength. A patented tripping device is designed to protect the operator in case of spring breakage. If one of the two activating springs breaks, the other spring actuates the trip. If both springs should break, the clutch automatically disengages. Springs are easily replaced in 30 sec. without stopping machine.

Capacity of press at bottom of stroke is 90 tons. The crankshaft has a $5^1/_{16}$-in. main bearing, a 6½-in. crank at pin, and a standard stroke of 4 in. Top of bolster front to back is 28 in., and top of bolster right to left is 40½ in. Bolster thickness is 4 in. and the distance from bed to slide is 21 in. Speed of the back shaft is 250 r.p.m.



The press shown here has a patented tripping device to protect operator in case of spring breakage.

New Dielectric Heater Is Portable

A new, electronic heater has been announced by *Radio Frequency Corp.*, Boston 34, Mass. This unit sends what may be described as a beam of radio waves oscillating 30,000,000 times per sec. through the material to be heated. Passage of the beam creates heat almost instantly, and the material is heated inside and out regardless of thickness.

This unit features portability, automatic operation with no knobs to turn or meters to read, and complete safety with no low frequency current appearing above the chassis.

The unit is adaptable to small soldering and brazing jobs as well as the hardening of very small diameters such as needles and fine wire, which cannot be hardened by larger machines operating at lower frequencies.

Gas Detector Protects Gas-Fired Equipment

A new gas detector for protection of gas-fired furnaces is being manufactured by *Jabez Burns & Sons, Inc.*, 11th Ave & 43rd St., New York 18.

The new instrument detects unburned gas from leaky or carelessly closed valves, or incomplete combustion; indicates on a dial the degree of concentration; and, whenever a predetermined concentration well below the danger point is reached, automatically operates an alarm or a control to shut off a gas valve in the supply line. It is equally effective for mixtures of flammable gases with inert gases, and for air-gas atmospheres.

Gas detector cells are mounted at convenient points for automatic and continuous sampling of the gases. During normal operation, a green light on the control box shows constantly; but whenever unburned gas reaches a predetermined concentration, a red light gives a permanent signal (and an automatic gas shut-off valve may operate as well), until the affected area is purged. Failure of current or of any part of the mechanism operates the alarm (or a gas shut-off) automatically.

● A new type chemical stripper that removes gilsonite, rubber base and metacrylate finishes is being offered by *Klem Chemicals, Inc.*, 14401 Lanson Ave., Dearborn, Mich. The manufacturer claims that this new stripper, called Klem #74, removes stubborn paints and enamels in sheets, that the paint film is not disintegrated, and no residue is left on the surface.

Sheet Feeding Table Has Toggle-Lever Design

For handling and feeding to presses and shears loads of sheet steel up to 10,000 lb., the *Lyon-Raymond Corp.*, 3727 Madison St., Greene, N. Y., have announced a toggle-lever type feeding table. Stock may be loaded on table by fork truck or overhead means either in stockroom or at the press. Table is portable for transporting loads, and hydraulic elevation allows leveling of load with press bed for efficient horizontal feeding.

The advantage of the toggle-lever design is the full support given to the entire length of the table top—particularly desirable in the case of long heavy loads. Lifting action is obtained by hydraulic pump through hydraulic cylinders which operate laterally against the toggle-lever mechanism. Table guides are inverted so that no uprights extend above table top.

The table top is 30 in. wide by 96 in. long; lowered height 22 in.; elevated height 34 in.; total lift 12 in. Extensions for the table top may be furnished for the support of loads wider than 30 in. and longer than 96 in.

Equipment for Inert-Gas Shielded Arc Welding

Two new pieces of equipment for inert-gas shielded arc welding have been introduced recently. The *Hobart Brothers Co.*, Troy, Ohio, announced a new a.c. welder designed for use with the Heliarc equipment supplied by the Linde Air Products Co., using helium or argon. This equipment can be used for welding magnesium alloys, aluminum, stainless steels, high carbon and other alloy steels, brass, Monel, Everdur, and other hard-to-weld metals.

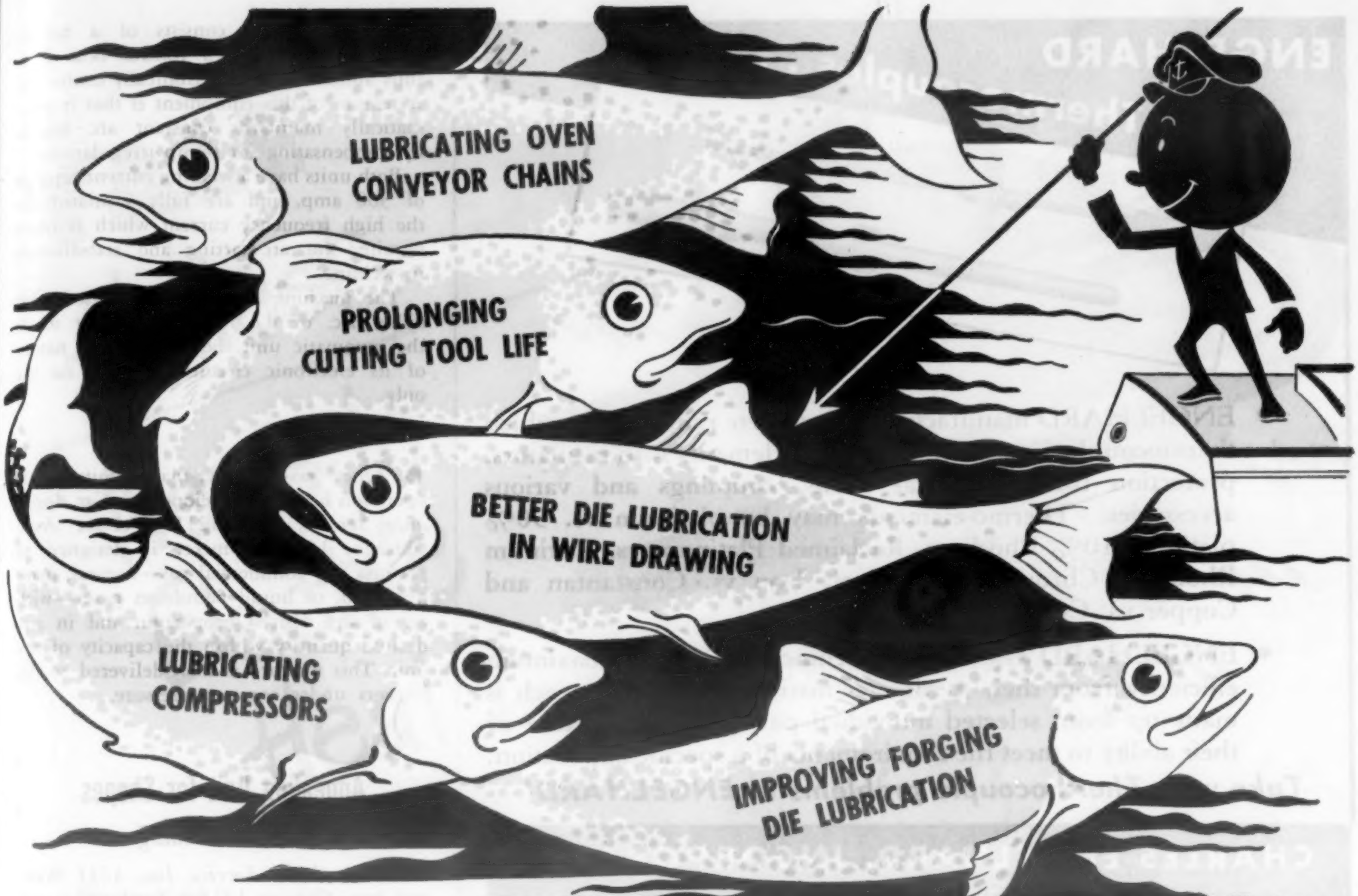
This model embodies high frequency stabilization to insure easy starting and dependable maintenance of the gas-shielded arc with practically no rectification of the a.c. current passing it. A window is provided through which the spark gap may be observed, with a door through which it may be reached for adjustment.

This a.c. welder is specially designed for inert-gas shielded arc welding.

Pressing a foot pedal starts the arc through the tungsten electrode, and simultaneously opens the valves permitting the shielding gas and the cooling water to flow through the special torch. Releasing the pedal breaks the arc, but permits gas and water to continue flowing for a predetermined length of time, which is adjustable up to 180 sec. This delaying action protects the weld metal from oxidation until it has had time to solidify after the arc has been broken. A strainer in the water line ahead of the valve is accessible through a hinged door for cleaning.

The *Air Reduction Sales Co.*, 60 E. 42 St., New York 17, has announced that it is marketing two new Heliwelding units, a machine type electrode holder, and an automatic unit. The machine holder is designed for mounting on a suitable travel mechanism for moving along the joint or for fixed position use with the work moving beneath the arc. It has the same barrel and rack as standard 1⅜-in. dia. machine gas cutting torches.

The automatic unit, designed for con-



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tinuous operation, consists of a holder, holder carriage and a control box. It is fully automatic and electronically controlled. A feature of this equipment is that it automatically maintains constant arc length, by compensating for set-up irregularities.

Both units have a welding current capacity of 300 amp. and are fully insulated for the high frequency current which is often required for arc-starting and stabilization in welding.

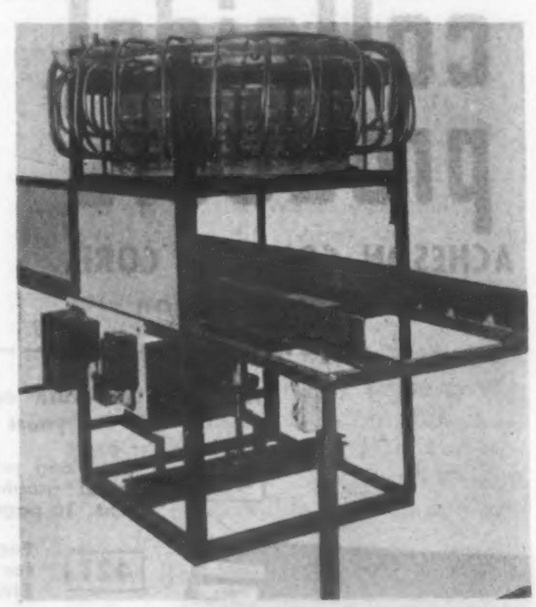
The machine holder may be used with either a.c. or d.c. welding current while the automatic unit, because of the nature of its electronic circuits, operates on d.c only.

● A new gas-air mixer that permits visible operation has been developed by *Gas Appliance Service, Inc.*, 1211 Webster Ave., Chicago, 14. The mixer is designed to pre-mix any commercial gas—natural, manufactured, or liquid petroleum gases—with air in any desired proportion and in any desired quantity within the capacity of the unit. This mixture is then delivered to the burners under constant pressure.

Annealing Unit for Shapes Prior to Rolling

Gas Appliance Service, Inc., 1211 Webster Ave., Chicago 14, has developed a gas-fired annealing unit for annealing the top section of washing machine tubs and similar shaped pieces, prior to a rolling operation.

The annealing chamber is fired by a series of high velocity burners which produce a uniform band of heat around the top section of the tub. In present installations 20 to 30 sec. are required for this section to reach annealing temperature, the time variation depending on size of tub and gage of metal used.



In this gas annealing unit the part is automatically raised to the annealing chamber and rotated.

This method of selective annealing makes it possible to anneal only that portion which requires further working, allowing the remaining part to retain its original work hardness. It can be applied to a variety of different shapes.

Direct Fired Heater Adaptable to Old Ovens

A new direct gas fired heater for paint drying ovens, core and mold ovens, moisture drying ovens and industrial processing ovens has been announced by the *Newcomb-Detroit Co.*, 5741 Russell St., Detroit 11. The heater mixes the products of combustion directly into the air stream. Both the main and pilot burners are approved enclosed pressure type using low pressure combustion air. There is no open flame in the production department and positive control is provided.

Cut-away view of the direct gas fired oven heater.

The heater is said to be particularly adaptable for "rejuvenating" old ovens with inadequate temperature ranges, insufficient capacity or inadequate heat distribution systems. It can be adapted to ovens of any design and readily fits into the space formerly occupied by the old heating system.

The heater is available in four standard units—5000, 10,000, 15,000, and 20,000 cfm. air capacities. Each of these units has a choice of burner capacities from 250,000 Btu.'s to 4,000,000 Btu.'s.

High Frequency Converter for Induction Heating

A new 20-kw. high-frequency converter for induction heating and melting, reported to have simple controls and safety interlocks, has been announced by *Ajax Electrothermic Corp.*, Ajax Park, Trenton 5, N. J. The new converter incloses all parts into one semi-portable unit that measures 44 by 44 by 58 in.

The electrical circuit of the converter is self-tuning, with frequencies varying from 20,000 to 80,000 cycles per sec., depending on the size and shape of the furnace coil to which it is connected. The converter is of the spark-gap type and has specially tipped copper electrodes in the hydrogen-atmosphere, water-cooled spark gap chamber.

To safeguard against damage to capacitor, spark gap, or furnace coils, an interlocked alarm bell rings if the converter is not flowing properly. The new unit can be used for steel melting up to 30 lb.; for brass and bronze alloys in melts up to 60 lb., and for melting gold, silver, platinum and other precious metals. Heating applications include such jobs as brazing, hardening and soldering.

News of... ENGINEERS COMPANIES SOCIETIES

Engineers

Glenn E. Hilliard, manager of the open-hearth department of the Brackenridge plant of Allegheny Ludlum Steel Corp., has been given the Allegheny Ludlum merit award, consisting of the President's Medal, a citation and $1000 in cash for developing techniques for using oxygen as a carbon reduction agent in the open-hearth. Under his supervision the process was first used commercially. The award was also given to *Robert T. Eakin,* plant manager, Carbide Alloys Div., for development of coal mining bits tipped with sintered carbide.

H. A. Grove has joined the Atlantic Steel Co., Atlanta, Ga., as metallurgical engineer, having formerly been with Republic Steel Corp., where since 1936 he had been a mill metallurgist on alloy flat products, specializing on stainless steel sheet and strip production. During the war he concentrated on tank and light armor plate. Previous connections had been with Aluminum Co. of America and Battelle Memorial Institute. He has been an instructor in metallurgy in the evening school of the University of Akron.

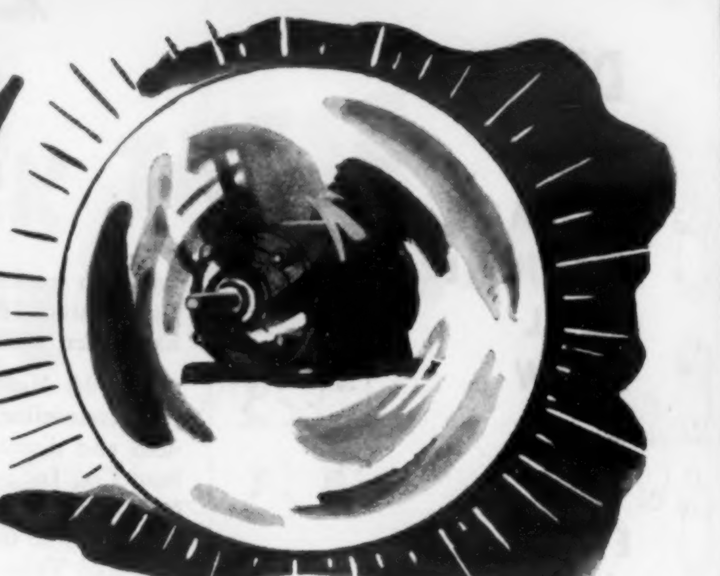
Robert L. Klein has left his position as director of research and development with the Presmet Corp., Worcester, Mass., fabricator of powdered metal parts, to become president, Windalume Corp., W. New York, N. J., a new company making aluminum windows for residences.

Vincent D. Barth has joined Battelle Memorial Institute to conduct research in nonferrous metallurgy, his more recent previous connections having been with Federated Metals Div. and Douglas Aircraft Corp. *Joseph Gurland* is also now connected with Battelle to engage in the same enterprise, holding a master's degree in chemical engineering and metallurgy from New York University. *Harold W. Herring,* mechanical engineer, is a new member, engaged in research on production materials and methods, having been design engineer for the Curtiss-Wright Corp.

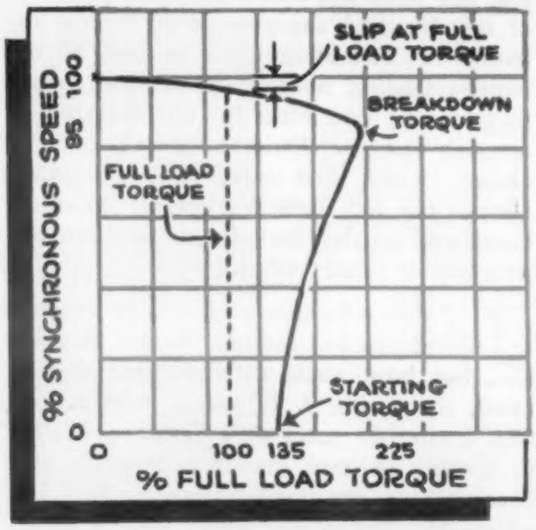
Professor *R. S. Green,* department of industrial engineering, Ohio State University, has been made editor-in-chief of the new book, "Design for Welding," issued by the James F. Lincoln Arc Welding Foundation. Professor Green has had earlier experience with the Blaw-Knox, Carnegie-Illinois and American Bridge companies.

Dr. *Irving A. Denison* has been appointed chief of the underground corrosion section of the National Bureau of Standards. He

Here's One Way to Choose Motors...



Sure, Your Local "Swami" can pick a motor for you in an instant! But if you want motor counsel you can *bank* on . . . you'll consult a reputable motor manufacturer. In place of crystal-ball gazing, he'll advise you to follow *practical* and *orderly* steps in arriving at *right* motor selection. For example . . .



First, Study Your Power Supply . . . voltage, frequency, number of phases; the p.f. required by your utility. Judicious selection will help balance your motor capacity . . . lower power costs. And check the voltage regulation — choose motors with enough torque to start and carry the load. Next . . .

Study the Driven Machine and surroundings. What hp? What starting torque? Will you need a horizontal or vertical motor — direct-connected, belt-driven or gear-operated? How about surroundings — ambient temperature, moisture, corrosion, dust. Each calls for a particular type of protection. Now . . .

Study Your Motor Characteristics. *A-c motors?* For most jobs they're satisfactory and economical. *D-c motors?* For wide speed range; for fast acceleration or reversal they may prove your best bet. *Synchronous motors?* When applicable they give you low-cost p.f. correction. You're *still* undecided? Call in your nearby Allis-Chalmers motor expert. He'll be glad to help you decide—with recommendations backed by 50 years of motor-building!

Wise Motor Choice Saves Power; Ups Profit!

YES, CRYSTAL-BALL GAZING methods are out when you're trying to get *maximum* return on your electric motor investment. Slip-shod selection usually results in over-capacity, high power and maintenance bills — the kind of costs that in the competitive era of tomorrow you won't be able to afford!

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News of...

ENGINEERS COMPANIES SOCIETIES

has been working in soil corrosion with the Bureau since 1929. He is a member of some half-dozen technical societies.

Charles Mahoney, metallurgist and industrial counsellor, has been made vice president and director of the William H. Bingham Co., Inc., Chicago 3. During the war he was chief metallurgist, Basic Magnesium, Inc. Prior to that he was chief metallurgist, Ken-Rad Tube & Lamp Corp. He has also been a consultant, providing design, engineering and market counsel.

Max Hansen, distinguished German scientist, has been appointed associate professor of metallurgical engineering at Illinois Institute of Technology. He is one of the world's leading nonferrous physical metallurgists. At one time he was director of research for the Durener Metallwerke at Duren, which first introduced aluminum alloys. He has authored several technical books and articles, including a book on the structure of binary alloys.

H. C. Edwards, chief engineer of research and development, Timken Roller Bearing Co., has been made director, that department, succeeding *J. F. Leahy,* who retired Oct. 1 after 45 years with Timken. *Walter F. Green,* assistant manager, research and development, becomes manager. Mr. Edwards had had much design and development experience with automobile and aircraft manufacturers.

Dr. *John P. Nielsen* has been appointed associate professor of metal science at New York University College of Engineering. For four years he conducted research for the Philips Laboratories, Inc. on X-ray equipment and electrical drilling of diamond dies. He had specialized in metal crystallography and physics of metals.

John D. Dale, president, Charles Hardy, Inc., has been visiting England, France and Switzerland to investigate powder metallurgical developments.

V. E. Lysaght is now directing sales of the Andres C. Campbell Div., American Chain & Cable Co., Inc., making abrasive cutting and "nibbling" machines.

George Stern, formerly chief metallurgist, has recently been appointed director of research of the American Electro Metal Corp., Yonkers 2, N. Y.

Fritz V. Lenel, formerly metallurgist, Moraine Products Div., General Motors Corp., Dayton, Ohio, has become assistant professor of metallurgical engineering at Rensselaer Polytechnic Institute. He will continue to do research and development work and possibly some consulting in powder metallurgy.

Companies

A contract for preparation of dies and stampings for the bodies of the 1948 Tucker

News of...

ENGINEERS COMPANIES SOCIETIES

automobile has been let to the *Hayes Body Co.*, Grand Rapids, Mich., which will ship stampings of the body sections to the Chicago Tucker plant in knock-down form for assembly and welding. Tucker has been considering purchase of a steel plant to insure steady supply of steel sheets.

A new concern for production of stainless-copper clad sheets is the *American Cladmetals Co.*, which will produce such sheets at its plant at Carnegie, Pa. It will produce them by the Kinney process on a completely mechanized precision basis. Such sheets have been produced as thin as 0.017-in. thick and up to 27 in. wide. Its heat transfer qualities is well adapted to cooking utensils. The original product consists of stainless on the outside for corrosion resistance and copper inside for heat distribution. Later the company may clad aluminum to steel and silver to steel.

The *Budd Co.*, Philadelphia, is making available to railroads and industrial organizations its extensive research laboratories, test facilities and engineering personnel under direction of Gen. G. M. Barnes, vice president in charge of engineering. The offer applies to small undertakings as well as major ones.

Harry Dixon, through the *Metallurgical Products Co.*, Brookline 46, Mass., has contract representation for all of New England, New York City, New Jersey and eastern New York for the following accounts: *Michiana Products Corp., A. F. Holden Co., Stanwood Corp., A. S. Richards Co.* and *North American Mfg. Co.* Mr. Dixon will also do consulting work on salt baths.

The Fafnir Bearing Co., New Britain, Conn., has created annual scholarships for any one of five engineering courses at Yale University in memory of Elisha H. Cooper, who served as Fafnir's first general manager. The scholarships are for $1000 per year, or $4000 for the entire course.

A new aluminum reduction plant to add 3,500,000 lb. of aluminum pig per month was due to start operations Oct. 31 at the Tacoma plant of the *Permanente Metals Corp.* A unique feature is the scrubbing equipment, consisting of carefully-constructed aluminum covers for individual pots, which trap the fumes, conducting them through washers.

The *General Bronze Corp.* has moved its plant to Stewart Ave., Garden City, N. Y., thus combining all eastern plants and offices.

The *James F. Lincoln Arc Welding Foundation* has issued a pamphlet explaining its annual engineering undergraduate award and scholarship program, the contest to close May 15, 1948.

Robert B. Seger and Andrew L. Olson, formerly superintendent and assistant superintendent, Lindberg Steel Treating Co., have acquired ownership and management of the

WHILE design engineers could undoubtedly think of a much more practical way of shoveling snow, they'd probably agree with one fact brought out by Mr. Goldberg's cartoon. Only steel can do so many jobs so well.

When a product needs rugged strength, toughness, light weight and high resistance to corrosion—when it must withstand intense heat or cold—when protection against fatigue, sudden shock or abrasion are imperative — when good looks and low price are important factors . . . then steel will usually provide the most practical and economical solution.

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UNITED STATES STEEL EXPORT COMPANY, New York
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U·S·S ABRASION-RESISTING STEEL to combat wear and friction.
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News of...

ENGINEERS
COMPANIES
SOCIETIES

Chicago Steel Treating Co., 333 N. California Ave., Chicago.

The *Mullins Mfg. Corp.* is spending nearly $1,000,000 at Salem and Warren, Ohio, to increase and improve facilities for making "Youngstown kitchens." Among new equipment are an enameling furnace, propane gas equipment, new presses, spray booths and drying ovens.

The *Harvill Corp.* has acquired a third die casting plant at 4358 Roosevelt Road, Chicago, which does a complete job from design and manufacture of die casting dies to production of aluminum, zinc, magnesium and brass castings. It will increase the company's capacity 50%.

The *Fairchild Engine & Airplane Corp.* has licensed its Al-Fin process for binding aluminum to steel to the *National Bronze & Aluminum Co.*, Cleveland, which will make some dozen items by the process.

A sound motion picture, "Looking Ahead Through Plexiglas," has been produced for the *Rohm & Haas Co.*, Washington Sq., Philadelphia, by the *Jam Handy* organization.

The *Shanafelt Mfg. Co.*, Canton 5, Ohio, maker of foundry products for 54 years, has moved to their new plant at 2623 Winfield Way N. E., Canton. Features of construction are expansive window areas, fluorescent lighting, radiant heating, etc. It is constructed specifically for the making of steel foundry flasks.

The *Lukens Aluminum Co.*, Dayton, Ohio, has been formed as an aluminum alloy die casting plant. It is named from R. E. Lukens, president, *Central Tool & Die Co.*, Dayton. The general manager of the new concern is W. B. Kindrick, with Charles Briggs as factory manager and James L. Erickson as director of sales and engineering.

Societies

A permanent stainless steel exhibit will be opened in early 1948 at the *Architects' Samples Corp.*, 101 Park Ave., New York, under sponsorship of the *American Iron & Steel Institute* and stainless steel producers. A feature will be a sectioned jet engine, showing numerous parts made of stainless.

The *Gray Iron Founders' Society* has adopted a "ten-year plan" for improvement. First year's activities consist of sustained trade paper advertising, organization of 40 local groups of gray iron foundry executives, a balanced technical development program, and extensive public relations activity.

The *Southern Assn. of Science & Industry* will hold a South-wide conservation conference Jan. 11-13 at Hotel Chamberlin, Old Point Comfort, Va., to "boost the use and halt abuse of the natural resources of the South." Fields covered will be soils, waters, forests, minerals, wildlife and marine resources of 14 southern states.

The *Gray Iron Research Institute* has named Daniel E. Krause as executive director, whose main work will be to bring closer liaison between its laboratory research at Battelle Memorial Institute and its affiliate foundries. Membership is composed of 16 companies, operating 22 foundries in the eastern half of the United States.

The *Resistance Welder Mfgrs. Assn.* has awarded its $750 annual prize to Julius Heuschkel for a second year in succession, the latest award honoring Mr. Heuschkel for his paper on metallurgical aspects of carbon steel spot welding. He is a welding specialist at the Westinghouse Research Laboratories.

The *Institute of Mining & Metallurgical Engineers* has awarded its Charles F. Rand gold medal to Eugene Gifford Grace, chairman, Bethlehem Steel Corp., for "distinguished achievement in mining administration." It will be presented in February.

Dr. William F. Meggers, chief, Spectroscopy Section, U. S. Bureau of Standards, has been awarded the Frederick Ives medal of the *Optical Society of America* for distinguished work in optics. He has been called the "dean of American spectrographers."

J. Schuyler Casey, president, M. H. Treadwell Co., Inc., New York, has been elected president of the *United Engineering Trustees, Inc.*, a corporation that promotes advancement of the engineering arts and sciences in all their branches.

The *National Assn. of Metal Finishers, Inc.*, Detroit, has elected five new directors: Albert W. Olson, Industrial Plating Works, Inc.; F. A. Truden, Southern Finishers, Inc.; John Hilfinger, Hilfinger Corp.; D. J. Griffin, Birmingham Plating Works; and Charles W. Logan, Logan Platers, Inc.

Meetings and Expositions

NATIONAL MATERIALS HANDLING EXPOSITION. Cleveland, Ohio. Jan. 12-16, 1948.

SOCIETY OF AUTOMOTIVE ENGINEERS, annual meeting. Detroit, Mich. Jan. 12-16, 1948.

INSTITUTE OF SCRAP IRON & STEEL, INCORPORATED, annual meeting. Chicago, Ill. Jan. 19-20, 1948.

INSTITUTE OF THE AERONAUTICAL SCIENCES, annual meeting. New York, N. Y. Jan. 26-29, 1948.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, winter meeting. Pittsburgh, Pa. Jan. 26-30, 1948.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, annual meeting. New York, N. Y. Feb. 15-19, 1948.

CRYSTOLON* hearth plates give long trouble-free service in heat treating furnaces. They are highly refractory and physically strong, therefore able to carry heavy loads at elevated temperatures. Their heat transfer properties are excellent and they offer great resistance to abrasion. CRYSTOLON hearth plates, like other Norton heavy-duty refractories, are built for elevated temperatures and the greater the heat the more reason to specify Norton Refractories.

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The Last WORD

by T. C. DU MOND

Coming—A Birthday

With this month's ramblings we complete a full twelve months of Last Wording. It's difficult to evaluate one's own work, but we hope our avowed aims were met. As we said 'way back in January, our aims were not lofty. All we wanted to do was provide a place for friendly interchanges of thoughts between editors and readers. This we think the department has been.

What an Outlook!

Last January we started another department. Even though we are not sure about the progress of this page, there is no doubt about our cousin on page 3. "The Materials Outlook" has really taken hold. We know this because of the comments which return to us. Pleased (irate) producers of materials credit the department with gaining (losing) business because of what has been said. For those in the parenthetical class above, the cause has not been due to misinformation; rather it has been because the information has been correct. We can't claim a perfect batting average. We have gone off half-cocked on a few occasions, but our fences are being mended so that the bulls are being kept out. Keep watching "The Materials Outlook," we have a feeling it will grow in its value to you as well as physically.

Only A Nephew

Prof. H. F. Moore, who has more than a nodding interest in shotpeening, wrote to tell us that the article "Shotpeening of Nonferrous Metals" in the November M&M was interesting. However, the professor takes exception to our statement that he is the father of modern shotpeening. It's not that the child isn't one to be proud of, but Prof. Moore feels that his relationship is more likely that of a nephew. As this student of shotpeening points out, Zimmerli, Almen, Lessells and Horger have stronger claims to paternity of this modern process.

An Unlikely Race

There is a strange race going on in this country. How it will end no one can foresee, but it is interesting. It seems that the people responsible for the output of steel keep one eye on the blooming mill and use the other eye to scan birth reports from all over the nation. So far, the percentage increase in steel production is one-third higher than the increase in population. That would be fine except for one thing. Each succeeding generation demands more steel products than the last. Thus, if we are ever to have enough steel capacity, we will have to call a moratorium on births, slaughter everybody when they reach social security age, or make a huge jump in steel-making capacity. Fortunately, leaders in the steel industry are planning the latter. Projects under way in 1947 and 1948 will increase ingot capacity by 2,500,000 tons. This increase is part of an expansion program which totals over one billion dollars since the end of the war.

What A Session

We should have questioned it when someone told us that a few Metal Show sessions were being held in the evening at 606 South Clark St. in Chicago. We couldn't recall any hotel there, at least none listed in the printed programs. However, another editor and this redactor found the address and went in. I suppose it could be called a technical session, but to me what went on on the stage seemed more like an exhibition—of epidermis. Even though we felt we were misdirected, my partner and I felt it would be rude to leave in the middle of things. Do you think that our politeness could have been due to the fact that we had a ringside table and that the girls weren't bad looking? Well, live and learn.

What's That Name Again?

We couldn't believe it, but recently a letter came to this office from a resident on Skunks Misery Road. The town owning this flavorful name is located in the fashionable section of Long Island. After the first shock passed, we wondered if the name came from misery the skunks suffered or misery they caused.

Sudden Thought

With all of the foremost nations of the world using up strategic materials like mad in their race for power there could be a happy ending. If they all run out of the necessary metals for jet planes, guided missiles and the like, isn't it possible that war may revert back to the conditions of centuries ago? If that were to be the case, wars would be abandoned, since a civilization trained in push-button war would find fighting less glamorous. We know there isn't the slightest chance for this to happen, but we can hope.

About Time

Like the weather, we all talk about fire but do little about it. Now comes Westinghouse with the announcement that its research laboratory is starting a project to learn all there is to know about fire.

Greetings

To those of you not receiving a personal greeting from various members of the staff, may we say here that we are thankful for your support, readership and loyalty and that we wish each and every one of you a bright and cheery Christmas and a most happy New Year.

Materials & Methods

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

December 1947

PUBLISHED SINCE 1929 AS METALS AND ALLOYS

THE SMOKE GOES UP THE CHIMNEY...

JUST THE SAME!

THE INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED BEATS TOUGH CORROSION CONDITION

This 554-foot chimney was built* in 1936 for International Nickel of Canada to handle gases from copper reverberatories and converters. Now, after ten tough years, the smoke goes up this chimney just the same as the day the stack was built!

TEN YEARS WITHOUT REPAIR

The gases contain SO_2 with moisture content slightly above atmospheric humidity. Despite this corrosive condition, up to the present time no repairs have been made to this stack, and no evidence of deterioration has been noticed.

HERE'S WHY:

The entire lining of this stack was built with acid-proof brick laid in Penchlor Acid-Proof Cement.** In addition the top fifty feet of this stack was further protected by using Penchlor Acid-Proof Cement for pointing the outside surface joints. Penchlor Acid-Proof Cement is a superior sodium silicate cement that is quick-setting and self-hardening. Its outstanding record of satisfactory service has been proved in chemical plants, steel mills, paper and pulp mills, oil refineries and smelting plants.

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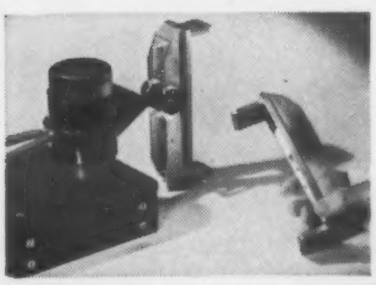

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When you add up all the parts in your plant that can be brazed, hardened, assembled, etc. by Ajax-Northrup induction heat—with greater speed and uniformity, less warpage and scale, and lower costs—you'll be amazed!

All jobs shown here can be done with one all-purpose Ajax-Northrup 6-kw. converter simply by changing work coils. That versatility is important, because the frequency converter is the greatest part of the investment, and the more jobs it does, the quicker it will pay for itself.

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Ajax-Northrup motor-generator equipment offers you the same savings and versatility on heavy work such as heating 5-in. bars for forging, or melting a ton of steel. Call on Ajax's 30 years of experience.

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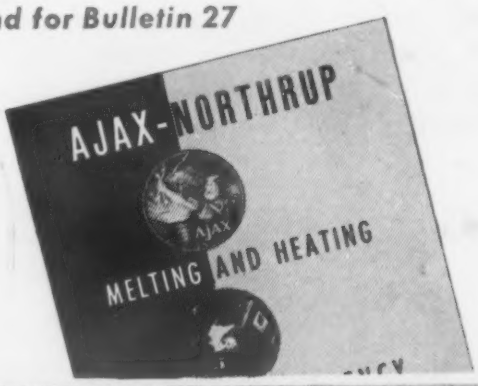
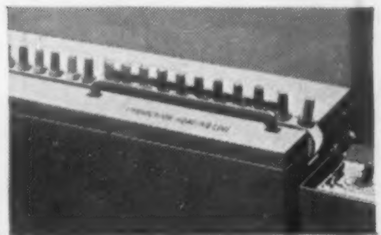


TOOL HARDENING, ETC.



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